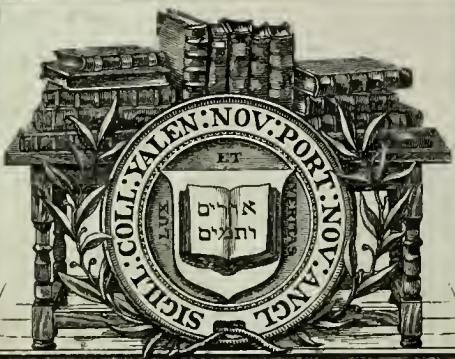

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ELECTRO-THERAPEUTICS.

ELECTRO-THERAPEUTICS:

A CONDENSED MANUAL

OF

MEDICAL ELECTRICITY.

BY

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PREFACE.

THE chief aim of the present volume has been the analysis of the principles which ought to govern our use of Electricity. The portion describing the practical applications which have been made, in various disorders, is not intended to be exhaustive, but it is hoped that enough has been said to satisfy the needs of the general practitioner. Reports of cases are purposely omitted, as their introduction would have extended the volume beyond the size designed for it.

BOSTON, June, 1874.

LIST OF AUTHORITIES.

THE following books are mentioned as likely to be of most use to those who desire to extend their studies in this department:

BALFOUR STEWART: Lessons in Elementary Physics. New edition, 1873. Containing an excellent brief account of the physical laws of Electricity.

GANOT: Elementary Treatise on Physics. Translated by E. Atkinson. Fifth edition, 1871. With a more extended account of the same.

ROSENTHAL: Electricitätslehre für Mediciner. Second edition, 1869, pp. 216, large 8vo. Is strongly to be recommended; its scope relates mainly to physical laws and descriptions of apparatus.

MORGAN: Electro-physiology and Therapeutics. Being a study of the Electrical and other Physical Phenomena of the Muscular and other Systems during Health and Disease, including the Phenomena of the Electrical Fishes. 1868; pp. 714, large 8vo.

ZIEMSSEN: Die Electricität in der Medicin. Fourth edition, 1872. Of this extremely valuable work only the first half has been printed.

DUCHENNE: De l'Électrisation localisée. Third edition, 1872. Contains a rich collection of cases and valuable special monographs; is very diffuse, and yet quite incomplete in some directions. Translated by Tibbits, of London.

ALTHAUS: A Treatise on Medical Electricity, &c. Third edition, 1873. A very valuable work.

ONIMUS ET LEGROS: Traité d'Électricité Médicale, 1872. A work of originality, and characterized by fairness; a good deal of matter that is not strictly "practical."

Benedikt: Elektrotherapie. 1868. New Edition, first part, 1874.

Beard and Rockwell: A Practical Treatise on the Medical and Surgical Uses of Electricity, &c. 1871.

Meyer: Die Electricität in ihrer Anwendung auf praktische Medicin, 1868. A translation is published by D. Appleton & Co.

Moriz Rosenthal: Die Elektrotherapie, &c. Second edition. Vienna, 1873.

The eight preceding works aim at a complete account of the physics, physiology, and therapeutics of the subject.

Brenner: Untersuchungen und Beobachtungen über die Wirkung Elektrischer Ströme auf das Gehörorgan im gesunden und kranken Zustande. 1868 and 1869.

Reynolds: Lectures on the Clinical Uses of Electricity. 1871; pp. 112. A truly admirable, practical work.

Tibbits: Handbook of Medical Electricity. 1873. A good and useful little book, less complete than might be wished, in some respects.

Cyon: Électrothérapie. 1873. The book deals exclusively with principles; to a very clear statement of these it adds free and incisive criticism of other men's work in the same department, and reports of a few original researches in physiology.

Neftel's work on Galvano-therapeutics is but a fragment.

Eulenburg's "Lehrbuch der funktionellen Nervenkrankheiten," though not in the least a treatise on electro-therapeutics, contains a great many scattered observations upon the subject, which deserve the attention of the student, perhaps as much as any formal text-book of electricity.

The "Nouveau Dictionnaire de Médecine et de Chirurgie pratiques" has, in vol. xii, a good article, with an extensive bibliography.

Erb: Ueber die Anwendung der Electricität in der inneren Medicin. 1872; 38 large pages. This lecture is No. 46 of Volkmann's klinische Sammlung; it is about as large as Reynolds's little book, and merits similar praise.

Middeldorp, Voltolini, Ciniselli, von Bruns, and others have written upon the surgical applications of galvanic currents.

Remak's "Galvanotherapie" cannot now be recommended as a guide to the student, however interesting as a monument of the author's genius.

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CHAPTER I.

PHYSICAL LAWS.

In order to form correct and consistent views of this important branch of our subject, it is worth while to remind ourselves at the outset of one general fact, namely, that when we use the terms "galvanism," "faradism," "contact-electricity," "friction-electricity," "magneto-electricity," "induced currents," etc., etc., we are speaking in each instance of one and the same force, only under different circumstances.

In the poverty of expression which marks our ignorance of all things that lie deeper than *phenomena*, we are permitted to speak of this force as a fluid, or as two fluids, a positive and a negative, which accumulate and disperse in various ways, and whose presence is manifested, now as a spark, now as an attractive or repulsive influence, now as a chemical transformation. The force, or fluid, if we prefer to call it so, may be generated in a glass-plate machine, in the thunder-cloud, in a steam-boiler, in a voltaic pile, or a Ruhmkorff coil; in every case it is the same force, and possesses the same properties, although in very different proportions. In the

following pages the term "Electricity" will be used in this broad sense. But as regards the therapeutic uses of electricity, we must direct our first attention to that form which is obtained immediately from the galvanic cell, singly or in combinations. The remainder of this chapter will therefore be understood as referring primarily to this, the galvanic or voltaic current, which we take for a standard at present.

All the phenomena of electricity,—the production of light, heat, chemical change, motion, attraction and repulsion,—can be measured. In the case of a galvanic battery, a certain amount of chemical action takes place, the measure of which is found, of course, in the quantity of the chemicals expended; to this chemical action, the development of electricity is, *cæteris paribus*, proportional; if the current when generated is transferred to a delicate loop of wire, the wire is heated to a proportionate degree; if passed through a coil, a proportionate magnetic effect is manifested in a neighboring bar or needle of iron; if caused to traverse a chemical solution (as in electro-plating), a proportionate chemical activity is generated. In expressing these facts, we speak of the electric current as possessing QUANTITY, as we speak of measurable quantities of heat generated by burning given weights of coal.[1] Faraday's voltameter is an instrument designed to take advantage of the principles just stated.

[1] The reader will observe that "quantity" is here attributed to heat and to electricity in the same sense,—a sense which does not imply bulk or volume. It would be improper to use the term in the sense in which we speak of a quantity of oxygen. This caution is given, lest the use of the expressions "electric fluid" and "current" might give rise to misconceptions.

It consists of a glass vessel containing water, into which two platinum tips are plunged, serving to transmit the current; the water, as is well known, suffers gradual decomposition, and the resulting gases being collected, furnish by their quantity an indication of the voltaic current that has been passing during a stated period. But a better test is furnished by the magnetic force which the moving current develops, and which is made available by means of the galvanometer, an important part of our apparatus, to be described more fully hereafter.

We must next take notice of a property which the metals possess in a high degree, and which is found indispensable in using and measuring the electric current. I refer to Conductivity, and its related term, RESISTANCE. In accordance with the laws of this branch of the subject, the quantity of the current is practically dependent, not solely upon the activity of the chemical or other physical processes which generate electricity, but also upon the goodness of the conductors employed in transmitting it. In other words, quantity is directly proportioned to the goodness of the material used as a conductor. And further, if two wires of pure copper, of different sizes, be successively used to conduct a given current, the quantity transmitted will be proportionate to the bigness of the two wires in either case; and if wires of the same bigness ("transverse section"), but of different lengths, be employed, the quantity will be inversely proportioned to their respective lengths. In other words, the attenuation and elongation of a conductor are two factors which diminish its conductivity in a uniform ratio; and these two factors in combina-

tion are known by the term Resistance, which is symbolized by the letter r.

Besides this resistance, which is variable, there is another source of resistance involved in the very generation of the current. It is well known that the cell (or "element") contains a pair of plates of different metals, plunged into a chemical solution. These plates are not allowed to touch one another in the solution; and in order to complete the circuit, the current of electricity is obliged to traverse the fluid in passing from one plate to the other. In making this passage a measurable resistance is encountered, which is sometimes made very great by the porous wall or diaphragm which separates the two metals; in certain kinds of batteries it is even purposely made greater by reinforcing the thickness of the diaphragm, in order to check waste, and obtain uniformity of action. The resistance thus encountered is called *essential*, or *internal*, to distinguish it from that previously described, which is called *non-essential* or *external*. Its symbol is R.

The term ELECTRO-MOTIVE FORCE is employed to designate the force or cause by which electricity is set in motion in the voltaic circuit. Its symbol is E. In the case which we are discussing, it has its origin in the contact of a metal plate with a fluid.

We are now prepared to state the formula for calculating the quantity of electricity traversing a given circuit. The actual current thus circulating would be equal to the electro-motive force, were it not for the resistances above explained. Or, in other words, *the actual current in any given case is equal to the electro-motive force, divided by the sum of the resistances.*

If we designate the actual current by the symbol I, then

$$I = \frac{E}{R + r}$$

This is the celebrated "Law of Ohm."

In affixing values to these symbols, it is commonly considered that the Daniell battery furnishes the unit of electro-motive force; that is to say, in the Daniell cell,

$$E = 1$$

The unit of resistance is obviously of great importance. The Siemens unit is that presented by a thread of mercury, one metre in length and one square millimetre in transverse section, at the temperature of zero, Centigrade. The unit adopted by the British Association ("B. A. unit") is often called the Ohmad or Ohm, after the discoverer of the law just stated. It is nearly one-twentieth greater than that of Siemens, or, more exactly,

$$\text{B. A. unit} = 1.0486 \text{ S.}$$

The letter I, just now employed, stands for the term "intensity," which is used by some of the best authorities in the sense which I have intended to convey by the phrase "actual current." This latter phrase has been used in order to avoid the confusion, which seems inevitable, between the terms "tension" and "intensity." It would be well to substitute some such word as "current,"[1] and to write the formula,

$$C = \frac{E}{R + r}$$

[1] Morgan, op. cit., p. 65. Clark and Sabine, Electrical Tables and Formulæ.

TENSION may be defined as the power which the electric current has to overcome obstacles. Such an obstacle may be presented by the atmospheric air, the resistance of which is overcome by the extreme tension of atmospheric electricity. It may be a sheet of glass, which is perforated by the spark from a Ruhmkorff coil; it may be the human cuticle, which, when dry, is almost as much a non-conductor as wood. In either case the quantity of electricity is something quite different from its power of overcoming resistances; a difference which may be illustrated by the laws of momentum, a current of high tension being represented by the penetrative force of a rifle-ball, and one of low tension by the shock of a cannon-ball falling a few inches by its own weight.

The human body presents a great resistance—several thousand units—to the passage of an electric current. The so-called "faradic battery" generates a current of such high tension that this resistance is of little importance. But a galvanic or voltaic cell, taken by itself, has a feeble tension; and when its current is conducted through the human body, a great part is lost, so that a physiological effect is scarcely perceptible. In order to impart the quality of tension, we arrange many cells in what is called the compound order, connecting each cell with its two next neighbors only, so that the total current is obliged to traverse the whole line of cells from one end to the other. Let us suppose such a series of the Siemens-Halske cell, of which the two terminals or poles are connected with two portions of the human body. The resistance of the body is not at all a fixed quantity, but we will assume it to be

$$r = 4000.$$

That essential to the cell, though somewhat variable, may be put at

$$R = 25;$$

while the electro-motive force is

$$E = 1.$$

With these values the formula

$$I = \frac{E}{R + r}$$

becomes, for a single cell,

$$I = \frac{1}{4025} = 0.00025;$$

which is a statement of the actual quantity traversing a given point of the circuit in a given time. But if ten cells are employed, arranged in the compound order, the formula becomes

$$I = \frac{10\ E}{10\ R + r} = \frac{10}{4250} = 0.0023;$$

which indicates that the working power of ten of these cells, when applied to the human body, is nine times greater than that of one cell. And if one hundred cells are used, we find that

$$I = \frac{100\ E}{100\ R + r} = \frac{100}{6500} = 0.015;$$

which implies an action sixty times as powerful as that of a single cell.

The chief source of internal resistance is furnished by the diaphragm, which may be made very thick and dense without impairing the value of the battery for medical uses. Of this, the Siemens-Halske cell presents an example.

In regard to the construction of batteries which generate large quantities of electricity, for heating wire for surgical purposes, it is sufficient to say that a very few large cells of great chemical activity are required. The reason for this change lies in the fact that the resistance presented by the wire-loop or cauterizer is very small compared with that of the human body.

But in constructing batteries for ordinary therapeutical purposes, no increase of force is gained by increasing the size of the cell. Large cells are, however, more easily kept in order. Force is gained by employing more powerful combinations. The electro-motive force of the Bunsen or Grove cell is about twice as great as that of the Daniell cell; and if we calculate the values of I, supposing E = 2 instead of = 1, we shall find the results, of course, doubled.

The DENSITY of an electric current is a term expressive of its degree of concentration at a given point. In entering a public building, a crowd grows thicker as the passage narrows; so in passing through a conductor of any sort the electric current grows denser as the conductor is made smaller. This principle has important applications in Medicine and Surgery.

It may interest the reader to know the absolute value of electrical force as compared with the more familiar forces of gravitation and chemical affinity.

The "absolute unit of force" is agreed upon as equivalent to the weight of one-tenth of a gramme, or more accurately, of $\frac{1}{9}\frac{0}{8}\frac{0}{1}$ of a gramme (= 1.57 grains Troy), acting for one second of time.

The B. A. unit of tension (called a *Volt*) equals 100,000 absolute units; the B. A. unit of resistance (called an *Ohm*) equals 10,000,000 absolute units.

Tension and electro-motive force are not convertible terms, but for the present purpose they may be taken as such; we are at liberty, at all events, to convert the formula

$$C = \frac{E}{R + r}$$

into numerical values in accordance with such an assumption. If then we have a cell in which E is equal to one volt, and $R + r$ to one ohm, then during each second of time there is generated an amount of force represented by the equation

$$\text{Current} = \frac{100{,}000}{10{,}000{,}000} = \frac{1}{100} \text{ of an absolute unit} = \text{one ``veber.''}$$

In the Daniell cell E is very nearly equal to 1 volt, but the resistance equals 2 or 3 ohms, so that the force generated equals, say $\frac{1}{2\,4\,0}$ of an absolute unit per second, or one absolute unit every four minutes. If such a current, derived from forty Daniell's elements (not of the Remak construction) be passed through a human body for the usual length of a medical application, that is for four minutes, the amount of force traversing a given portion (section) of the body, during each of those 240 seconds, will be represented by the equation

$$C = \frac{40\ E}{40\ R + r} = \frac{40 \times 1 \text{ volts}}{(40 \times 2.4) + 4000 \text{ ohms}^1} = 0.0097 \textit{ vebers},$$

or 0.000097 absolute units.

---

[1] 4000 is here assumed as an average resistance of a portion of the human body.

During the whole period, the force in circulation amounts in all to $240 \times 0.0097 = 2.33$ vebers. And since one veber of electricity decomposes 0.00142 grains of water, the amount of work done by such a current, in passing through the body, may be estimated as equivalent to the decomposition of

$$2.33 \times 0.00142 = 0.0033 \text{ grains of water in four minutes,}$$

which answers to 0.024 cubic inches of mixed gases. In other words, such a current would have to act 1200 minutes upon the human body in order to decompose one grain of water in that body.

It will readily be seen that the result will be nearly the same when Remak (Siemens) elements are used instead of those of Daniell. A certain portion (not very considerable) of the electro-motive force is wasted in overcoming the high "internal resistance" of this cell; and if Bunsen or Grove elements be used instead of Daniell's, the result will be nearly doubled, owing to the high electro-motive force developed by these two important combinations.

The above conclusions have been verified by some experiments recently made by myself upon the decomposition of pure distilled water by a battery of forty Siemens's elements, the current of course not passing through the human body at all. The resistance offered by the water appeared to be about equal to 2000, though slightly fluctuating. With this value for r, and letting R equal 25, the *calculated* result amounted to the decomposition of 0.0058 grains of water in five minutes; the *experimental* result gave a decomposition of 0.00568 grains in the same period.

A current of this strength, if properly interrupted

and directed to the main plexuses and nerves of the human body, would doubtless soon produce a state of continuous tetanus of all the limbs, which could not be long supported by a well person. This comparison will enable the reader to understand the vast interval which separates the physical from the physiological effects of electricity. In fact, the two classes of operations are strictly incapable of being measured against each other. We shall have little to do, comparatively speaking, with the chemical action of electricity, and a great deal with the physiological.

CHAPTER II.

MODES OF GENERATING ELECTRICITY.

This force is so constant an attendant upon the organic processes of animal and vegetable life, that a description of its spontaneous origin in nature would lead us far out of our way.

Living nerves and muscles possess their proper electric current, flowing in definite directions; the laws of this current have been thoroughly studied, and may be found stated in well-known text-books.[1] A description of these phenomena is not included in the purpose of the present work.

Atmospheric electricity may be dismissed with a word; its qualities resemble those of frictional electricity, but the number of its reported therapeutical successes is very small. The electricity of the torpedo and the electric eel also possesses very high tension; the apparatus, or battery, which furnishes the electricity of these creatures is extremely interesting, but we must refer our readers to current works on Natural History for descriptions, and turn to matters which concern us as practical physicians.

Electricity is produced artificially in many ways, of which the best known may be described under the heads of Friction, Contact, Induction, Magnetism, Heat.

[1] Fully explained in Morgan's work above named.

1. Frictional electricity was known to the ancients. Its phenomena were investigated and identified with those of atmospheric electricity by Franklin, from whose name it has been proposed to form the rather ugly word "Franklinization," to signify the application of this current in medicine. The Leyden jar, and the glass-plate and cylinder machines, are well known. Holtz's "Electrophorus"[1] provides the same quality of current in very large amount, by an ingenious application of the principle of induction to the common plate machine. The "franklinic" current has found favor in London, at Guy's Hospital, the National Infirmary, and one or two other places. In Germany its chief advocates are Schwanda, Frommhold, and Clemens; it is far from obtaining general adoption at the present time, although some successes are undoubtedly attributable to its use. Its effects are nearly equivalent to those of an induction apparatus of high tension.

2. Contact-electricity bears the names of two illustrious discoverers, Galvani and Volta. It is also properly called dynamic electricity, as distinguished from the static form just described. Its trivial names of "constant current," "battery current," "direct current," "primary current," may conveniently be replaced by that of "galvanism."

The physician will occasionally see "thermic batteries," which give rise to a current somewhat like that of contact-electricity. But for all practical purposes he may consider that "galvanism" is derived from moist

[1] Drawn and described in Althaus's "Medical Electricity," 2d and 3d ed.

cells, as "faradism," to be presently described, is derived from coils of wire. These two terms will be regularly employed in this work to denote the two classes of currents with which we have to deal in the practice of medicine.

A battery is composed of a single cell, or of many. The essential parts of a cell are a pair of dissimilar metal plates, with wires leading from them, and a fluid in which the pair of metals is bathed. The plates must not touch each other in the fluid. The poorest form of a moist battery is the voltaic pile, in which there are no separate cells (*i. e.*, glass jars), but each pair of metals is kept from mutual contact by a bit of felt or moistened leather called a diaphragm, while the pairs are simply piled upon each other, and the whole is moistened with acidulated water. This instrument yields at first a strong current, which soon becomes greatly weakened and very irregular.

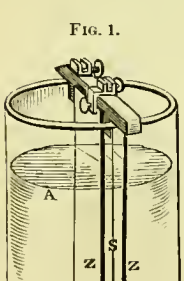
There are a great variety of disks and chains and belts, made to wear on the body, which certainly generate an electric current that may be turned to practical account in medicine; they are, however, a little dangerous, unless used with great caution, as burns of the skin are frequently caused by them. Strictly speaking, the "galvanic disks," etc., of commerce are moist batteries, analogous to Volta's pile, and depend upon the moisture of the skin to keep them in action. But to return to the subject.

Batteries containing but one fluid are technically called inconstant, because the quantity of electricity furnished by them varies from minute to minute. Those containing two fluids, one for each metal, between which a porous diaphragm is placed, are called constant, and

may act with but slight diminution of force for several months.

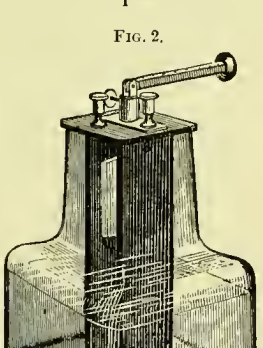
Of the former class are several very popular and useful batteries, of which the positive metal is usually zinc, while the negative may be of platinum (Smee's battery), or lead or silver coated with finely divided platinum (Frommhold's), or carbon (Stöhrer's). The fluid is diluted sulphuric acid. Zinc and carbon plates in a mix-

FIG. 1.



Smee's Battery.

FIG. 2.



Grenet Element, with arrangement for lifting zinc out of fluid.

ture of water, sulphuric acid and bichromate of potassa (Grenet's) form a powerful combination, adapted to the operation of electro-cautery, or if made with small cells, to ordinary therapeutic uses. Small zinc-carbon batteries are also constructed, to be worked by the bisulphate of mercury; they are very convenient. Pincus's battery is a combination of zinc and silver with chloride of silver; it is more constant than those previously described, and is very portable, but is easily put out of order.

Constant batteries usually comprise a porous vessel of

earthenware, containing one metal, bathed in one fluid; this vessel is set into a larger jar, containing the other metal and fluid. The standard element of this class is that of Daniell, composed of zinc (in a weak dilution of sulphuric acid) and copper (in a strong solution of sulphate of copper). This excellent battery requires frequent cleaning, and the porous cells are apt to become clogged with a crystalline deposit of metallic copper; both which disadvantages are entirely avoided in the

FIG. 3.

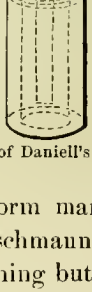
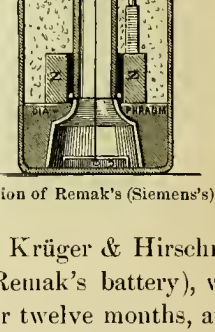


Diagram of Daniell's Battery.

FIG. 4



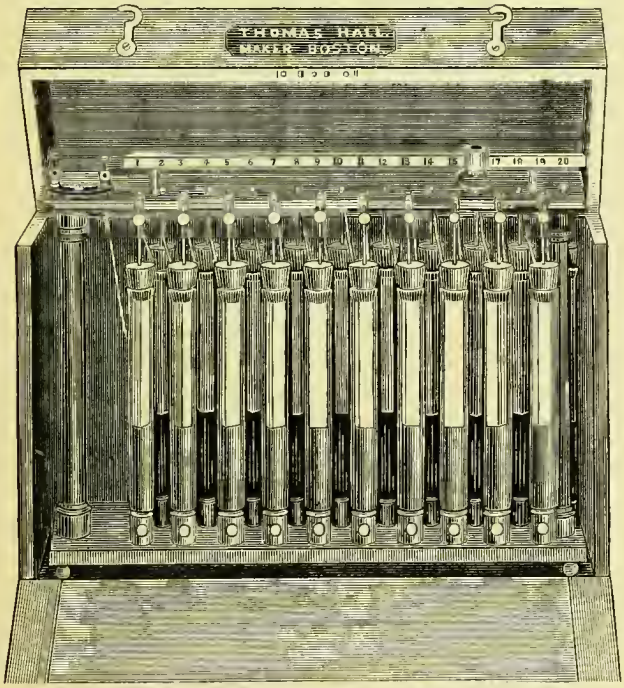
Section of Remak's (Siemens's) Cell.

modified form manufactured by Krüger & Hirschmann (now Hirschmann) of Berlin (Remak's battery), which needs cleaning but once in six or twelve months, and is certainly one of the most desirable batteries for office use, though too bulky to be made portable.[1] Muirhead's is a Daniell's without sulphuric acid. Leclanché's is a very constant battery, requiring but little attention. Its porous cell contains a piece of carbon, packed tightly

[1] I have seen two batteries of this sort in which the copper had made its way through the diaphragms of some of the cells. In my own battery, which has been in use two years, this has not occurred; and the action is nearly as powerful as it was twelve months ago, though nothing has been done except replenishing the fluids.

with a mixture of peroxide of manganese and carbon in coarse powder; the positive metal is zinc, in a solution of sal ammoniac. It is said to evolve a perceptible quantity of ammonia; this, if true, is an objection (and

FIG. 5.



Beetz-Leclanché Portable Battery.

the only one) to its adoption, but in a single cell the odor can scarcely be detected. Professor Beetz has contrived a very portable and convenient modification of this battery, which is described by Ziemssen[1] in terms of ap-

[1] Op. cit., 1. Theil, p. 208.

proval; it is manufactured by Meyer in New York, and Hall of Boston. I am not able to speak fully of its qualities. It is, however, an inconstant battery, like most of the portable ones. The porous cell of the large battery requires repacking in one or two years' time, or the old cells may be replaced with new ones at a considerable cost. Grove's battery contains zinc in diluted sulphuric acid, and platinum in nitric acid; Bunsen's is like Grove's, except that carbon is substituted for platinum. Both are very powerful and useful. To avoid the annoyance of the fumes of hyponitrous acid, a mixture of bichromate of potassium and sulphuric acid (of each four parts) and water (eighteen parts) may be substituted for the nitric acid in the last-named batteries. They are seldom used for purely

FIG. 6.

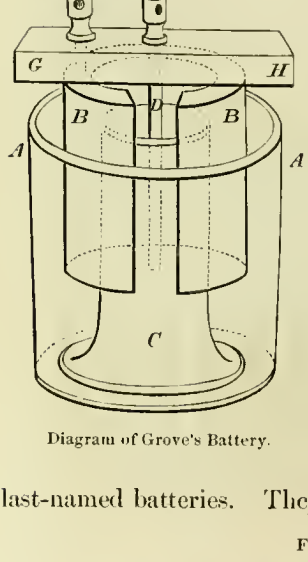
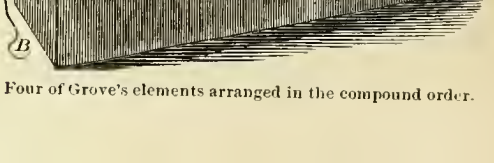


Diagram of Grove's Battery.

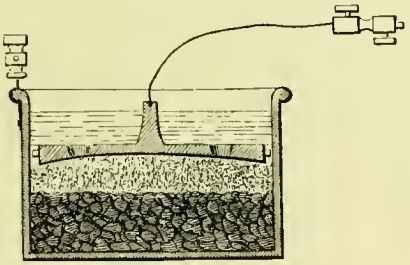
FIG. 7.



Four of Grove's elements arranged in the compound order.

medical purposes, except as supplying the motive force to induction machines. The "Eagles Battery"[1] is composed of a leaden box, in the bottom of which five pounds of sulphate of copper are placed, over that a

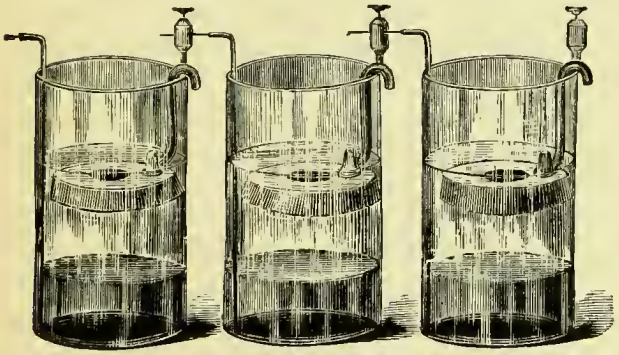
FIG. 8.



The Eagles Battery.

layer of sawdust an inch thick, and on the sawdust a plate of zinc. Water is then poured in, and the cur-

FIG. 9.



The Gravity Battery.

rent becomes established in a few hours. The "Gravity Battery" is composed of a disk of copper at the bot-

[1] "The Telegrapher," July 19, 1873

tom of a jar, upon which crystals of sulphate of copper are heaped; at a considerable distance above these a plate of zinc is suspended, and enough water is poured in to cover the zinc. In time the sulphate of copper impregnates the lower layers of water, but does not reach the level of the zinc, so that the battery possesses two perfectly distinct fluids, and is in fact as constant as most others. This is certainly a very valuable form of battery; the "Eagles" ought to be too, but has not yet been tested in medicine.

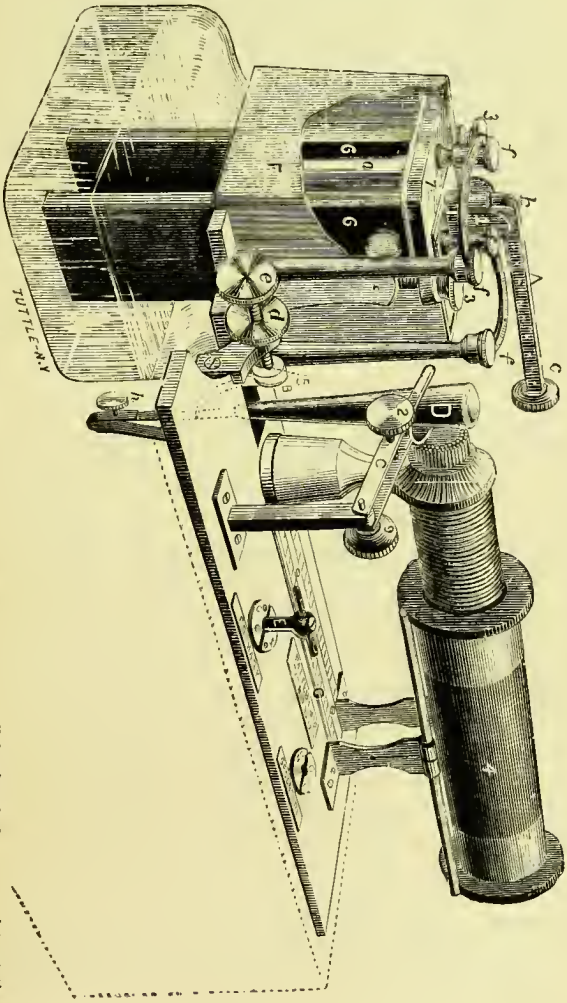
3. Induction-electricity, in the form most useful in medicine, was discoved by Faraday, and is conveniently styled "faradism."

The Ruhmkorff coil, in medicine, commonly goes by the name of the faradic coil. But the size of the wire employed, and the number of turns, differ greatly in the two instruments. The Ruhmkorff is constructed with a very large number of turns of very fine wire in the outer coil, and a very few turns of large wire in the inner coil; this arrangement develops a current of enormous tension, capable of traversing many inches of air, while the spark from the medical apparatus will scarcely pass an appreciable distance through air.

As to the physical principles which govern the production of induced currents, the following very brief statement may be given:

Any galvanic current, from whatever source derived, may be supposed passing through a single wire (A), close beside which, and parallel to it, a second wire runs (B). The two wires are insulated from each other. If the current in the first wire is broken ("opened"), a current is generated by induction in the second wire. If

the current in A is caused again to flow ("closed"), another current is generated in B, but in the opposite



Faradic Apparatus of the Galvano-Faradic Manufacturing Co. Upon the secondary coil is placed the numeral 4; at the foot of the sliding standard, which supports it, is a graduated scale of distances; the hammer (D) is upright, and is furnished with an apparatus for retarding the rate of its vibrations.

FIG. 10.

direction. The currents in B are of momentary duration, and alternate in direction.

In apparatus constructed for medical use, A is laid up into the primary coil, and B into the secondary coil, which is made hollow in order to receive the primary. In this arrangement the wires A and B are obviously parallel one to the other. Into the wire A of the primary coil, the current from a cell or a pair of cells is then introduced. One of the wires which conduct the current from the battery is so connected with an automatic hammer, that the continuity is constantly broken and renewed, at the rate of from four to several hundred times in a second, which gives rise to a rapid succession of currents in alternate directions, in the secondary coil B.

In the coil A, however, each turn of wire is obviously parallel to the next turns in the same coil. Hence arises another induced current in the inducing coil itself. This is commonly called the "extra current," and this term is recommended as avoiding ambiguities of nomenclature, which have unfortunately crept into the description of this subject. Owing to constructive reasons, the extra current is perceived only in one direction. It is very easy to prove this by the experiment of fastening the automatic hammer so that it cannot play up and down; if the connection between the coil and its motive power (the cell) is then alternately broken and renewed by the operator's hand, the person holding the electrodes feels a shock at breaking, but none at all when the current is again introduced.

The shocks of the secondary coil, though alternating in direction, are by no means equal in both directions; those due to the opening of the current in the primary

coil are so much superior in strength, that the others may be comparatively neglected, and we speak of a positive and a negative pole, in accordance with the direction of this stronger current only.

In describing the treatment of diseases by a faradic machine, it is not generally of the first importance to state whether the current from the primary or the secondary coil was employed.[1] There is considerable variety in the construction of these instruments, but the secondary or larger coil is on the whole most used. The ordinary "sledge apparatus" of Du Bois-Reymond is sometimes constructed in such a manner that the outer coil is not well adapted for the production of muscular contractions. Duchenne's apparatus has the same peculiarity, which consists in the use of a great length of very fine wire in the secondary coil. Another variety of apparatus (Kidder's) has three or four coils, superposed and variously united.

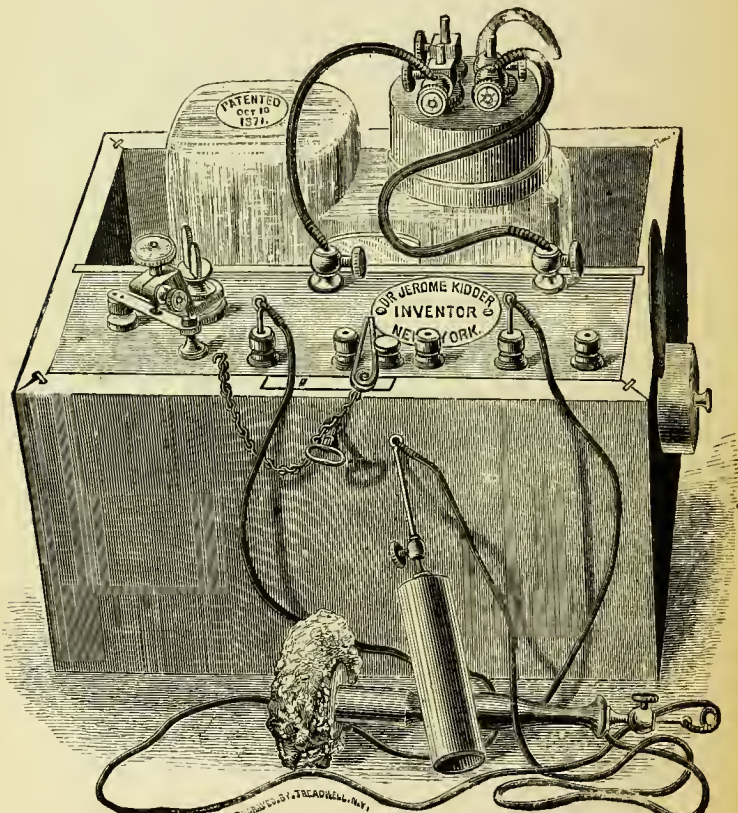
The strength of the extra current is increased in proportion as the secondary coil is withdrawn. The reverse is the case with the current in the latter coil. This enables us to graduate the strength of either current by sliding the outer coil back and forth. It must be added, that a good deal depends on the power of the cell which supplies the current; a Bunsen's or a Grove's gives by far the most powerful effects. A hollow metallic cylinder sliding over the coil furnishes a powerful damper or

[1] Some authors speak of the currents generated in the first, second or third coil as "primary induced, secondary induced currents," etc., respectively. It is better to avoid such phrases, as tending to confusion. The expressions, "current from primary and secondary coils" cannot be misunderstood.

regulator of the current; its principle of action need not be explained here.

Not only is the outer coil made hollow to receive the

FIG. 11.



Kidder's Faradic Apparatus, with *four* coils, and Smee's Cell, which can be tipped up so as to remove the plates from the fluid.

inner, but the inner is itself hollow, in order to receive a "core" or cylindrical bundle of soft iron rods. These

assist very greatly in developing the current. The principle upon which their action is explained is about to be stated in the next section, viz.:

4. Magneto-electricity. Strictly speaking, this is another form of induction-electricity. If an insulated wire is wound round a bar of soft iron, as a thread is wound around a spool, and a galvanic current is passed through the wire, the iron bar becomes magnetic for just so long a time as the current continues to flow.

This fact points to an intimate relation between the forces of electricity and magnetism. Such a relation is further shown by the converse experiment, in which a permanent magnet is brought rapidly into the neighborhood of a coil of wire, and again rapidly removed; at both moments, that of approximation and that of removal, a momentary current of electricity is generated in the coil of wire. By giving the coil a rotary motion, by means of a crank, we can cause it to make very rapid approaches and recessions; in this manner is generated a current which resembles the faradic in most points. An assistant is required to turn the crank, which forms a decided objection to the practical use of this instrument; yet the fact that it is always ready at an instant's notice must make it a desirable instrument for such emergencies as may arise during surgical operations, or for the resuscitation of drowning persons.

The core of iron rods, above described, is made magnetic by the currents in circulation around it, and while thus magnetized reacts upon the coil, in the way of strengthening the current in the latter. Thus in effect the faradic coil is dependent for a great part of its action

upon the principle of magneto-electricity; and the term "electro-magnetic battery" may properly be applied to it.

5. Thermic electricity. This form of the current is developed by heating the point of junction of two dissimilar metal plates. A combination of bismuth and antimony is commonly used; but alloys of various kinds are used to replace one or the other of these metals. Thermic batteries are very little used for medical purposes; they are not economical, and are liable to breakage, or cracking of the metals or alloys.

CHAPTER III.

PHYSIOLOGY.

It is well known that the motor nerve, when stimulated by electricity, responds by producing a contraction of the muscles under its control. The laws regulating this function have been made the subject of most laborious and exact research, and may be considered, to a great extent, as resting upon a basis of demonstration.

We commence, as heretofore, with a statement of the laws of the galvanic (voltaic) current. Of these, one of the most important is that which was stated by Du Bois-Reymond, in 1848, of which the following is a free translation:

"That which awakens the response of a motor nerve, and causes the contraction of its muscle, is (not the absolute value of the density of the current at any given moment, but) the alteration in this value from moment to moment; and the motor stimulus which follows these alterations is powerful, in proportion to the rapidity with which the latter take place, and to the greatness of such variation within the unit of time."

Of this law, the part inclosed in brackets must be modified under some circumstances; for the strength or density of a current is often the circumstance which (in combination with fluctuation in strength) decides a contraction. We will state the law in more familiar language, indicating the above correction, as follows:

"A mild current, flowing without interruptions, commonly fails to arouse to a perceptible activity the motor function of a nerve.[1] Strong currents, without interruptions, are capable of evoking the functional activity of motor nerves, and of most other forms of nerve tissue. But the rise or fall in the strength of a current produces a far more active stimulation than the steady passage of a current; the force of such stimulus is proportionate to the rapidity with which such alterations occur, and to their extent, the most powerful stimulus being caused by cutting off the current entirely, or by again introducing it."

These statements are but a *résumé* of observed facts. The theory employed to explain these facts may be sketched as follows:

It is a well-established fact that if the poles of a galvanic battery are placed upon different points in the course of a motor nerve, the portions in the neighborhood of the two poles are affected in opposite ways. At and near the positive pole, the irritability of the nerve is lessened as long as the current continues to flow; the nerve does not respond so readily to stimuli applied at that point; while in the neighborhood of the negative pole the opposite condition exists. Whilst in this condition the nerve is said to be "polarized;" it is in the condition called "Electrotonus." Further, the term Anelectrotonus is applied to the modification produced by the positive pole (anode), and Catelectrotonus to that produced by the negative (cathode).

When a galvanic current is suddenly caused to pass through a nerve—or when the current is suddenly with-

[1] Practically, at least, upon the living subject.

drawn, or is caused to fluctuate suddenly—in either of these cases, the nerve passes rapidly from the quiescent to the polarized condition, or *vice versâ*, and a stimulus (shock) is communicated. The muscular contraction caused by such a shock is but a single one, usually of momentary duration. By breaking and renewing the current we produce a rapid succession of such contractions, and if this is done with great rapidity the contractions appear to run together into one "tetanic" spasm. Some mechanical contrivance—for example, a cogged wheel, or a piece of clockwork—is necessary in order to produce this latter effect with a galvanic current; when properly managed, the experiment is a very neat one, and enables us to imitate very closely the operation of a faradic apparatus.[1] Reversing the experiment, we may cause the faradic coil to give a single shock, or a succession of slowly-repeated shocks; the effect upon the function of a motor nerve is a good deal like that of single galvanic shocks. This will serve to recall to mind the principle already laid down, that all forms of electricity are but one force. In speaking of certain kinds of paralysis, we shall have occasion to revert to this point.

The faradic current stimulates a motor nerve in a state of health, under the same law which governs galvanic currents. If it were possible to generate an

[1] It would not be safe to infer that the galvanic current, thus treated, can replace faradism for general purposes. The quantity of electricity is much larger than that generated by the coil apparatus; and though the apparent effect upon a muscle may be the same, the reaction upon the nerve of sight and the central nervous system is vastly greater than that of faradism, and might easily prove injurious if used indiscriminately.

induced (faradic) current without fluctuations or interruptions, its action would be essentially that of the galvanic. This, however, is impossible with a faradic apparatus. Onimus and Legros[1] have recently tried Ladd's magneto-electric apparatus in a case of peripheral paralysis of the facial nerve; but in spite of the great quantity of electricity furnished by the machine (sufficient to heat a considerable length of No. 21 platinum wire to redness), they failed to obtain the peculiar action which galvanic currents (and not faradic) possess in this disease.

The great stimulating force which a faradic or a magneto-electric current possesses, is largely due to its high tension, or power of overcoming obstacles; its inferiority, in certain cases, as in some forms of facial palsy, is ascribed to its feebleness in respect to quantity, which may easily be demonstrated with a sensitive galvanometer-needle.

When, however, we find that an apparatus for magnetic induction, like Ladd's, which generates a great quantity of electricity, fails to act upon paralyzed muscles, while a moderate galvanic current acts with great vigor, we are obliged to seek another explanation. This explanation is partially furnished by the greater *duration* of the galvanic shock. Fluctuations in the density of a galvanic current itself lose some of their power as stimuli of muscles and nerves if they are made excessively brief, for time seems to form an essential element in the perception of the electric stimulus by the organ. In medical practice no such excessively brief shocks are given with the galvanic current; we interrupt by hand,

[1] Op. cit., p. 596.

and the shock has commonly a duration of at least a second, while the faradic current occupies but the minutest fraction of a second.

When the galvanic current has been traversing a nerve or a muscle in a certain direction for some time, the organ appears to become fatigued, and reacts less briskly to the "closure-shock." While in this condition, a current applied in the opposite direction will act with greater vigor than if no current at all had been applied.

If we desire to take advantage of these facts, and produce a very powerful reaction, we employ an instrument for instant reversal of the direction of the current. The poles of the battery are kept constantly applied to the body, but by turning the handle of the instrument the direction of the current is changed, so that what was the positive pole becomes negative, and *vice versa*. This procedure is called the Voltaic Alternation.

The explanation of the process is as follows: At the positive pole the nerve or muscle is in a state of depressed susceptibility (anelectrotonus); instant suspension of the current produces a rapid disappearance of the depression, which has the effect of a stimulation; a simultaneous introduction of the negative pole produces a second stimulation, which is added to the former, producing a contraction of double vigor. At the other point of application, stimulation occurs under similar laws, but is less vigorous. By repeating the reversals at intervals of a few seconds the organ is brought into a state of high excitability. The effect upon nerves of sense is less thoroughly understood, but is doubtless similar to that upon the motor nerves; in particular, the

case of the auditory nerve deserves mention, to which we shall return presently.

Pflüger's "*contraction-law*" is an important development of the law of Du Bois-Reymond. In its strictness it is applicable only to the dissected nerve, and not to the nerve of a living and healthy body; yet there can be no doubt that its main principles hold good even in the latter case, modified, of course, by physical conditions. The nerve does not receive and transmit a galvanic current like a telegraph wire; it is rather like an uninsulated wire laid through water, carrying a part, but losing most of its current. It was unquestionably a mistake upon the part of Benedikt to insist upon the superior conductive power of nerves; they lie imbedded in tissue nearly equal in this respect to themselves; and this fact makes it very difficult, if not impossible, to establish an exact harmony between laboratory laws and those of the living body.

Notwithstanding such difficulties, Du Bois-Reymond's doctrine of electrotonus has been tested in a satisfactory manner by Eulenburg, Erb, and Samt, and still more recently by Cyon.[1] The nerves of the forearm were chosen as the subject of demonstration, and it was clearly shown that where the positive pole was laid upon a nerve, its capacity for responding to stimuli was diminished; where the negative, its capacity was increased.

Pflüger's law, which also can be demonstrated more or less perfectly upon the living subject, explains the

[1] Op. cit., p. 140.

comparative action exerted upon a motor nerve by ascending and descending currents—by strong and feeble currents—by the positive and the negative poles at the moments of closure and opening. These facts are summed up in a brief formulary, before giving which a few leading principles should be stated.

a. Nerves increase in irritability in the ascending direction. Of two irritated points, the one situated nearest the spinal cord responds most readily to a given irritation. This is a fact, independent of any theory of electrical action, and appears to apply to sensitive as well as to motor nerves.[1]

b. "The closure-contraction depends on the cathode; the opening-contraction upon the anode." In other words, the stimulus is felt at the cathode (negative pole) when a current commences; when a current is broken, stimulation occurs at the anode (positive pole).

c. The cathode has, in general, the more powerful action.

If, then, we desire to produce a stimulus with the expenditure of a minimum of electric force, we apply the negative pole above the positive, nearer the spinal cord, and cause the current to flow as suddenly as possible. The contraction of muscle thus produced is called "cathode-closure-contraction." The current, in this case, is of course an ascending current, flowing from the positive to the negative pole, in the direction of the spinal cord.

Currents are arranged by Pflüger in four classes, the first of which is the ascending current, which we have

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[1] Upon Rutherford's authority, Jour. of Anatomy and Physiology, p. 329, 1871.

just described. The reaction of each succeeding class is harder to produce, and requires a stronger current than its predecessor.

1. Ascending current, contraction at closure.
2. Descending " " opening.
3. Descending " " closure.
4. Ascending " " opening.

This law may be stated more simply by disregarding the direction of the current (which is perhaps an accidental circumstance), and stating the name of the pole which is applied nearest the central end of the nerve. We have added the customary (German) symbols, which are easily understood and will be employed in future:

1. Kathode-closure reaction, Ka S Z.
2. Anode-opening[1] " A O Z
3. Anode-closure[1] " A S Z.
4. Kathode-opening " Ka O Z.

Pflüger further stated that with weak currents a shock at opening is not felt; with moderate currents shocks are felt both at opening and closure. This is irrespective of direction, or nearly so. Currents of extraordinary force interfere with themselves, so to speak; the pole nearest the muscle impairs, for the time being, the power of the nerve to transmit the excitation derived from the upper pole. Such extreme currents are not applicable in medicine.

Brenner, of St. Petersburg, has founded a system for treating diseases of the ear, upon principles analogous

[1] Nos. 2 and 3 of these tables are by some authorities transposed.

to those of Pflüger's law. He believes that the auditory nerve reacts as regularly as the motor nerves under galvanic stimulus. But it is evidently impossible to apply either pole to the auditory nerve, while in Pflüger's experiments both poles were placed upon the motor nerve; this circumstance has occasioned peculiar difficulties, and a great deal of controversy has arisen, some authorities having rejected Brenner's conclusions as totally unwarranted. But, in general, they are accepted as applicable to most healthy persons.

Brenner insisted strongly upon the reasonableness of the principle that "when one pole is placed near a nerve and the other at a distance, the nerve obeys the nearer pole." His whole theory is based upon the assumption that the auditory nerve will obey the pole which is placed upon the mastoid process, or in the meatus, or upon the skin in front of the tragus, while it remains indifferent to the other pole, which is to be held in the hand. If the positive is held in the hand the current is "ascending;" if the reverse, it is "descending." Now Pflüger's law, as we have seen, is evidently explicable by the rules of polar action. The upward or downward direction of the current, though stated in his formulæ, is not the essential circumstance. If the current flows *upward* the negative pole is nearer to the nervous centres; and the action of the negative pole is the essential determining element of the reaction. And the same of Brenner's law; if the current flows from the hand to the ear, the negative pole is nearer to the auditory nerve, and its action is the essential element of the reaction. Brenner makes the further postulate that "the reaction upon closure depends on the cathode; that upon opening on the anode."

With what has been said, it will be easy to convert Pflüger's law into a law which expresses the reaction of the auditory nerve. A current of moderate strength, at closure, gives the first reaction, if the negative pole is placed at the ear. A somewhat stronger current gives not only this reaction, but also a reaction at opening, when the positive is placed at the ear. These are Nos. 1 and 2 of Pflüger. Nos. 3 and 4 are not producible upon a healthy ear, as the brain would not bear the current that would be required.

We will now describe Brenner's method of testing the reaction of a healthy auditory nerve, and the way in which he records what he calls the "normal formula." This formula is generally obtainable with a moderately strong current, which is safe to use. In performing the experiment a wire rheostat, and a current-reverser, are required; the former in an accessory circuit, the latter in the main circuit. A contrivance for breaking the circuit is also necessary; one worked by the pressure of the foot is very convenient (called "pedal rheotome"). The principle of the rheostat is such that when it is graduated to zero no current of any consequence flows through the body; if the operator understands his instrument he may safely begin with twenty or even forty cells in circuit, since the graduation commences with doses equivalent to $\frac{1}{400}$, $\frac{2}{400}$, etc., of the total force.[1]

Having made sure that his conducting apparatus is in perfect order, the operator commences by introducing, we will say X or XX, Daniell's elements into the circuit. The rheostat is connected, and graduated at zero.

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[1] Upon an approximate estimate; making the bodily resistance = 4000 S.

The negative pole, well wetted, is placed upon the mastoid process, or just in front of the tragus of the ear to be tested; the other pole is held in the hand of the other side. The electrodes must not be lifted or stirred during the experiment. If the patient feels giddy, or queer in the slightest degree, suspend operations. Commence by introducing ten[1] resistances in the rheostat, equivalent to $\frac{1}{400}$ of the current; then twenty, thirty, and so on; keep the circuit broken, but give at each step in the scale a shock, by passing the current suddenly, and again breaking it. At a degree of intensity which varies in different persons, the first evidence of acoustic reaction is obtained; the moment of closing (making) the circuit is marked by the perception of a sound, whistling, hissing, ringing, and so forth, according to the individual tested. If the patient hears such a sound, we write down the number of cells of the current, and the graduation of the rheostat required to produce it, and proceed to test other reactions.

As the negative pole is supposed to be placed at the ear, the first reaction in the experiment is a "cathodic" reaction, dependent on "closure" of current. We repeat the experiment, using a rather stronger current, allowing the current to flow for a time; the patient hears a continuation of the sound, dying away gradually; this is the second or "cathode duration" reaction, of the normal formula. Thirdly, we break the current—"cathode opening"—and *no sound* is heard. Fourthly, we reverse the direction of the current without altering the poles, then close the poles—"anode closure"—and obtain no reaction; fifthly, we allow the current to flow—

[1] Some rheostats are graded from one up to ten units.

"anode duration"—and again no reaction; we break the current after half a minute's passage—"anode opening" —and the sound is again heard, though feebly and briefly, constituting the sixth test.

The same moderate strength of current is used in developing all these tests. Increasing its strength will not compel the normal nerve to react where it at first fails, namely, at the third, fourth, and fifth tests.

If we express the normal formula by symbols, we first write the number of cells in Roman letters, and then the grade of the rheostat in Arabic numerals. We will assume a moderate force of current:

XX 50 Ka S K (*Klang*, sound).
Ka D > (sound dies away).
Ka O — (no reaction).
A S —
A D —
A O K (feeble sound).

"The capacity to react in the normal physiological manner to the electric stimulus is the *conditio sine qua non* of the health of the auditory nerve." Such is Brenner's statement. The presence of a normal reaction, however, does not prove that the nerve is entirely healthy.

A nerve which first reacts under XX 50 at cathode-closure, may react under XX 40, or 30 at the second or third trial; this increase of excitability is to be expected in a healthy nerve; it is called "secondary reaction." "Tertiary reaction" is obtained by testing *immediately after* the current has been reversed, but not by an actual voltaic alternation, which would be dangerous; the current must be shut off before reversing it.

The following changes in the auditory nerve are said by Brenner to be detected by the galvanic current:

1. Simple hyperæsthesia, with greater readiness to be stimulated by the tests of the "normal formula."

2. Hyperæsthesia, with a qualitative change in the formula. This implies that sounds are heard at Nos. 4, 5, and, in rare cases, at 3; sometimes the sounds heard at these moments are unusual in character, and differ from those heard at Nos. 1, 2, 6.

3. Hyperæsthesia, with reversal of formula; when Nos. 3, 4, 5 alone are heard.

4. Hyperæsthesia, with reversed formula, heard on the opposite side. Thus, if the left ear is supposed affected, and the galvanic tests are applied to it, the *left* ear hears Nos. 1, 2, 6, too readily; and the *right* ear hears Nos. 3, 4, 5. This is called a "paradox-reaction."

5. Reversal of formula, without hyperæsthesia.

6. Torpor of the nerve; which is very difficult to demonstrate.

All these changes unquestionably occur. It is only a question, how far such altered reaction is entitled to rank as a diagnostic sign of disease. A careful reading of Brenner's work will show that the ordinary means of aural diagnosis are mostly sufficient; in a few cases electricity appears to lend valuable information. We will here mention such points as appear most clearly valuable.

First. The existence of abnormal reactions proves that the nerve is somehow affected, and that the deafness, etc., is not solely attributable to the condition of the media of transmission of sound.

Second. Tinnitus with hyperæsthesia of reaction (a frequent combination with deafness) is commonly bene-

fited or cured by the positive pole; that with anæsthesia by the negative, or by the opening of the positive.

Third. When galvanism does not relieve tinnitus at all, the seat of the trouble is not in the auditory nerve. If we can then prove that the meatus, middle ear, and tuba Eustachii are sound, we ean diagnosticate central lesion, according to Brenner.

Fourth. The normal formula often returns after a course of galvanic treatment, and sueh a return is generally a token of improvement.

Wreden employs a procedure differing from Brenner's. He introduces a catheter eontaining a silver wire through the tuba Eustachii as far as the tympanic cavity; he then causes a concealed button, attaehed to the wire, to project from the catheter two millimetres into the cavity; the wire and button then serve to convey the eleetrie current. By this method he obtains a much stronger auditory reaction; the sensation of pain (trifacial) is less, and the effect upon the facial muscles (faeialis) is eonsiderably stronger than is the case in the ordinary method. Wreden considers that the sound heard during the passage of electric currents is due to the contraction of the muscles of the tympanie cavity, whereby variations in the intra-labyrinthine pressure are produeed.

The laws of Electrotonus are applicable to voluntary muscular fibre as well as to motor nerves, with the exception that only the portions between the poles are polarized; whereas, in the case of nerves, the influence is propagated for a distance along the nerve, outside of the poles.

The voluntary muscles can be brought into action either by the direct application of electricity to their

substance, or indirectly, by applications made to their motor nerves. If a single shock is employed, the result is the same in both cases; a brisk and momentary contraction occurs; and this may be prolonged into an apparently continuous contraction (tetanus), by making the shocks succeed each other very rapidly, as above described.

Involuntary muscles respond by a slower contraction, which lasts for a time after the current has ceased, and tends to propagate itself along the adjacent fibres. Such contractions may be observed in the intestine, the lower two-thirds of the œsophagus, and so forth.

When a voluntary motor nerve has undergone a certain kind of degeneration, it becomes incapable of conveying the impulse of volition, and of responding to the electric stimulus. The muscle, however, retains the power of responding to a galvanic shock, provided the latter be not too brief. To excessively brief shocks, and to the stimulus of faradism, it is partially or completely unable to respond. A condition much resembling this is produced by poisoning with woorara or coniin, of which the paralyzing action is confined to the nervous tissue. Such facts appear to prove that the muscles possess a power to contract, independently of the nervous influence. But the mode of contraction in these cases is strikingly peculiar. The muscle, when stimulated by galvanic shocks, does not contract so instantly, nor is its contraction so brief; it is said to react sluggishly (träg), and appears to behave more like involuntary muscles. In a well-marked case of this kind it is curious to observe that the tardy action of a paralyzed muscle, to which we are making direct application, is sometimes anticipated by the lively jerking of adjacent

muscles which happen to be aroused by offshoots from the main current. Thus, if we are at work upon the extensors of the hand and fingers, we may observe the hand first shut with a quick impatient movement, and directly afterwards open with a slower motion; and more singular still, we may find the extensors remaining more or less contracted for a minute or more, if we do not shut off the galvanic current. But a *very powerful* galvanic current applied to a superficial motor nerve, in a state of perfect health, will also produce a tonic contraction of muscles, as may easily be shown upon the nerves of the forearm.

A healthy muscle reacts promptly when the electrodes are applied to its substance; it is believed in this case to respond to the indirect stimulus of its intra-muscular nerves, and not to a stimulation of its independent or "Hallerian" irritability.

A muscle which, through exhaustion, has lost the power to contract, may regain its power if an uninterrupted galvanic current is passed through it. If exhausted by previous galvanization, the direction of the current should be the opposite of that which caused the exhaustion. The same is true of nerves. In the practical applications of electricity, similar results are of constant occurrence, and are often testified to by the sensations of refreshment experienced by patients, in cases where no muscular contractions have been produced.

A very important phenomenon attending muscular contraction is the evolution of heat, which, in the case of muscles kept in a tetanic state by means of the faradic current, is very considerable, amounting in one instance[1]

[1] Ziemssen, op. cit., p. 100.

to a rise of 4.4° Centigrade, or about 8° Fahrenheit. This rise in temperature is due to the chemical transformation or combustion which goes on as a result of muscular action; consisting of an increased consumption of oxygen, and exeretion of carbonic acid, with consumption of the albumen of the muscular tissue, increase in the amount of creatin and creatinin, and development of a free acid in the muscle. To this it should be added, that the circulation increases in rapidity, constituting a second though subordinate factor in the production of heat. The bulk of the muscle is decidedly increased during the process. The simple passage of a galvanic current without interruptions does not raise the temperature. It will readily be seen that these facts have great therapeutical importance, and enable us to characterize the faradic current as an alterative remedy, accelerating the changes of tissue.

The muscles of the skin respond, by contraction, to the electric stimulus, as they do to that of pinching and stroking; the result being the production of *cutis anserina*. This is not simply a reflected action, but may be produced in portions of excised skin.

Wherever muscular fibre exists, it may be made to contract with more or less readiness by electricity; it is needless to speak at length of the rectum and bladder, which are well known to be easily accessible; the heart can be punctured by needles, to convey a direct stimulation by the current; the spleen contracts (at least in dogs) when cutaneous faradization is used; the gall-bladder probably can be made to contract, through the walls of the abdomen, in the living man; the diaphragm is easily caused to contract, when the phrenic nerves in the neck are faradized.

The cutaneous bloodvessels act as one might expect. Galvanization and faradization seem to effect a brief stimulation of the sympathetic system, followed in a very few minutes by a relaxation, a decrease in arterial tension, a distension of the capillary system. Faradization of the skin, especially if applied in a painful manner, very quickly produces a blush of the surface, and a moderate elevation of temperature at the point irritated. In this case the stimulation and paresis of the sympathetic act locally with great precision; but the disturbance of circulation may be propagated to many other parts, central or peripheral, occasioning congestions or hemorrhages in some instances. The brain is certainly affected, we cannot say exactly how, when pain is felt; we know how often convulsive movements depend on irritations like those of the faradic "cutaneous current;" and how, in other cases, inhibitory actions are evoked; but this subject need not be pursued, as it is only indirectly connected with our own. The faradic stimulation of the nerves of common sensation has probably nothing specific in its action, but is simply an extremely convenient way of irritating without destroying.

The cutaneous pain produced by the galvanic current is of a burning or prickling nature, like that of a mustard poultice; the faradic current gives a stinging sensation. Muscular contraction communicates a sensation totally independent of the cutaneous nerves; the faculty of perceiving this has been named "electro-muscular sensibility."

Cutaneous sensibility is more readily excited by rapid, than by slow faradic currents. To accomplish this, the current from the secondary coil is best, and the skin is to be thoroughly dried before applying it; by this ma-

nœuvre, instead of passing *en masse* through the entire skin (which is the case when the latter is moistened), the currents are forced to seek the pores of the skin as the only good conducting channels; in each pore they become condensed into a fine bundle or pencil, and by concentration are enabled to act more powerfully upon the subcutaneous nerves. The pain disappears the moment the current is suspended.

Another way to increase the pain of faradization consists in making the pressure of the electrodes very light. If, therefore, our object be to make the muscles contract with the least pain, we shall employ a well-wetted electrode, and press it firmly on the skin; and when it is so applied we shall introduce a current with slow intermissions.

A local irritation of the skin, resembling urticaria, comes on in very rare cases after faradization, and may last a day or two. In other very rare cases the reaction appears to be normally very feeble, and pain can scarcely be felt under very severe applications.

A faradic current often gives a sensation of tingling, or numbness, or cold, when applied to a nerve of sensation; other queer feelings, as of trickling water, or a breeze of air passing over the surface of the skin, are referable to the same cause.

At the point where the positive pole of a strong galvanic current is applied, little pain is usually felt, and not much redness is produced. The presence of an acid may easily be demonstrated, due to electrolysis of the fluids of the body, and the metal plate of the electrode, if polished, becomes blackened. At the negative pole alkalies are formed. Sometimes minute, round, blackish points appear under the skin, which upon close exami-

nation are seen to be incipient vesicles; the base of the latter is attacked by the free alkali, and a minute destruction of tissue occurs, giving rise to an ulcer. Such results are usually to be avoided by care.

Much skepticism has existed regarding the practical value of physiological facts as applied to electro-therapeutics. Men who stand high in this specialty have contributed to this skepticism by their careless way of drawing inferences contradictory of physiology from their own supposed clinical experience. It can hardly be necessary to urge upon the reader the inestimable value of having a truly scientific basis for our therapeutical researches. Physiology, however imperfectly known, must be accepted as the best guide we possess; it is a better guide than bare conjecture; and all true progress in therapeutics must bring our practice into increasing harmony with the known rules of healthy and diseased action in the organs of the body.

One great obstacle to a rational basis of electro-therapeutics has been supposed to lie in the difficulty of bringing the brain and the spinal cord under the influence of the galvanic current. The bones of the skull were supposed to be such poor conductors of electricity as to preclude the possibility of any important amount traversing the brain of a living person. This difficulty has been proved to be entirely specious. Well-guarded galvanoscopic needles, introduced through holes bored in the skulls of animals, have demonstrated that the brain is traversed by considerable quantities of electricity when the poles are applied to the usual places at oppo-

site points on the skull. And, as the brain is one of the best conductors in the body, it requires no credulity to accept the results of the experiments of Ziemssen, Erb, and Burckhardt, which show that the current in traversing the brain obeys the well-known physical law, in accordance with which the greatest force is found to pass in the straight line connecting the two poles, while weaker side-currents are to be detected in all other parts of the brain. Identical results, as regards facility of transmission, have followed the application of similar tests to the spinal cord inclosed in its bony sheath, the inner ear, and the abdominal viscera. In traversing the cranium the current seeks by preference the sutures, and still more the foramina which abound at the base and in the frontal region, some of which are rendered still better conductors by the presence of large bloodvessels.

The human body possesses no very badly-conducting constituents, excepting the epidermis, hair, and bones. We are justified in considering it as we should a piece of metal of the same shape, in respect that a current traversing the metal, or traversing our bodies, diffuses itself through the entire bulk of matter, although strongest in the direct line connecting the two poles. The nerves are not the very best conductors, but are as good as most other parts of the body, and there is no physical difficulty in the way of our believing that a pole placed on the back of the neck, and another on the lumbar region, transmit a good share of their current through the spinal cord, though we cannot doubt that every part of the trunk is more or less visited by feeble derived currents.

Those who denied the possibility of transmitting the electric current through the skull employed the theory of reflex action to account for certain phenomena refer-

able to the brain; and this theory has been carried so far as to be offered in explanation of the phenomena of sight and hearing, which occur when the eye and ear are galvanized. The absolute superfluity of such a theory is seen from the simple consideration that the globe of the eye is itself a better conductor than the other tissues of the face, so that the retina could not lie in a more advantageous situation for receiving the current. It has been repeatedly remarked by authors, and has been quite recently observed by the writer in the case of a patient, that a galvanic current passed through the human pelvis may arouse a distinct sensation of taste, such as might occur during galvanization of the face. Such phenomena have been believed (as by Duchenne) to furnish direct evidence in favor of the unlimited capacity of the peripheral nerves for producing "reflex action;" while to others, among whom the writer is content to stand, the fact observed seems to point to an excessive local susceptibility to feeble side-currents.

Benedikt has been known as a prominent supporter of the reflex theory of the origin of auditory impressions perceived during the passage of galvanic currents, but his hastiness and want of exactness have done much to discredit his opinions.

In regard to the Brain, the views of Meynert, who, from anatomical and pathological evidence, has assigned the voluntary motor function to the gray matter of the anterior and parietal lobes, are strikingly supported by the experiments of Hitzig and Fritsch,[1] who have succeeded in obtaining combined muscular actions of the

[1] Trans. of the Berliner Med. Gesellschaft, Apr. 6, 1870.

extremities by means of the electrical stimulus applied to definite regions of the cortex of the anterior lobes, on the side opposite to that where muscular action appears.

The latest experiments of this physiologist were made upon an ape's brain,[1] in which all the motor points were found located in the one convolution situated in front of the fissure of Rolando—the gyrus præcentralis of Ecker.

Prof. Ferrier[2] has carried these researches further. He has shown that the convolutions form separate and independent centres; such centres are demonstrable for movements of the eyelids, face, mouth, ear, neck, hand, foot, and tail. Crossed action is the rule, but many muscles of the mouth, tongue, and neck are bilaterally co-ordinated from each hemisphere. The anterior parts of the hemispheres are the chief seat of voluntary movement and the unquestionable seat of intelligence. The irritation of the corpora striata causes preponderant flexion, and a rigid pleurosthotonos; of the corpora quadrigemina causes preponderant extension and rigid opisthotonos. The cerebellum is the co-ordinating centre for movements of the eyeball. In rabbits each lobe of it is a definite centre for changing the axis of the eye. Nystagmus, or oscillation of the eyeball, is an epileptic affection of the oculomotor centres in the cerebellum. The equilibrium of the body is dependent upon the maintenance of the integrity of these centres. "Discharging lesions" of the various centres are, as Hughlings-Jackson suspects, the proximate causes of the

[1] Berliner klin. Wochenschrift, No. 6, 1874.

[2] West Riding Lunatic Asylum Medical Reports, vol iii, 1873. Brit. Med. Jour., April 26, 1873.

various forms of epilepsy, and chorea is similar in its pathology.

A remarkable disturbance of equilibrium[1] attends the passage of a current transversely across the base of the brain of the human subject. In this experiment the electrodes are applied between the lobe of the ear and the mastoid processes, on both sides of the head. When the current is introduced the body leans towards the side of the anode, giddiness is felt, and the eyes execute certain nystagmoid movements. The eyeballs also move slowly in the direction in which the body leans, and then suddenly turn to the opposite side, repeating these acts in a rhythmical sequence. When the current is opened, similar movements are executed, but in the opposite direction. While the current is passing, the head does not retain its position fixedly, but relaxes gradually. None of these phenomena occur when the current is passed from the forehead to the occiput, or when one pole is placed on the occiput and the other is applied by a double electrode to the two sides of the head simultaneously. Hitzig considers it probable that central organs exist, destined to receive impressions from the "muscular sense," by which we are enabled to retain our balance. Such organs, if existing, would certainly be placed in symmetrical positions on the right and left of the median line. Transverse currents, therefore, would place them in contrary electrical conditions; one would experience the "positive modification," the other the "negative;" and this would at once impair the faculty of judging of the position of the body. Bren-

[1] Hitzig, in the Berliner klin. Wochenschrift, No. 30 1872.

ner's "Untersuchungen" contains similar but less extensive observations.

Breuer,[1] after a careful study of the functions of the semicircular canals, has come to the conclusion that the loss of equilibrium in Hitzig's experiments is due to some alteration effected in these organs by the galvanic current. He considers that the terminal nervous apparatus in the ampullæ is irritated by the current; or, that it experiences an electrotonic modification, as is the case with the retina (Helmholtz) under galvanic stimulation; under these conditions it responds with its specific action, to wit, the sensation of movement of the body.

Still more recently Hitzig[2] has formulated a "law of contractions" for the cortex, which appears directly the converse of that known as Pflüger's; the latter, however, applies only to peripheral organs. (P. 46.) Action is most readily evoked by a voltaic alternation, in which the negative pole applied to the cortex is suddenly made positive; next, by closure at the anode (No. 3 of Pflüger); next, by reversal of pole from positive to negative; next, by closure at cathode (No. 1 of Pflüger). Morphine does not change, and ether scarcely influences the normal excitability of the cortex under electrical stimulation; the same is true of artificial apnœa.

Giddiness may be produced by either class of current, applied in the neighborhood of the head and neck, though very seldom by the faradic current.

Sleep is often assisted, and sometimes comes quite unexpectedly, when a galvanic current has been passed

[1] Med. Jahrbücher der k. k Gesellsch. d. Aerzte in Wien, 1874, I. Heft, p. 110.

[2] Berliner medicin.-psychol. Gesellschaft; in the Berl. klin. Wochenschrift, No. 52, 1873.

through the brain; but this result is observed, now and then, when other parts of the body are electrized. It is quite likely that these actions are the result of a modification of the cerebral circulation, through the agency of the sympathetic system.

The intellectual functions are sometimes stimulated, or perhaps we ought to say exhilarated, by direct galvanization of the brain. The giddiness of which we spoke is a higher degree of a sensation usually said to be "indescribable," but sometimes called a "swimming," or a "lightness," or an agreeable "sense of freedom." The excess of this sensation, we would add, is far from agreeable.

The retina is best stimulated by applying one pole to the closed eyelid, and the other to the back of the neck. In favorable cases two colors are seen, one in the centre of the field, the other in a ring around the first. That which, under the positive pole, is perceived as centrally situated, occupies the periphery when the negative is applied, and *vice versa*. The effects of closure and opening of the current are characterized by a similar mutual inversion of the positions of the two colors. Different observers see very different colors under the same stimulus.

The sense of taste is easily stimulated by direct galvanization of the tongue. Besides this, it is frequently the case that we find a patient speaking of a coppery or sourish taste, or something like bad soda-water, when the current is applied about the neck; in such cases the nerves of taste are doubtless reached by side-currents. It is probable that the production of acids or alkalies by

the electrolytic agency of the current plays no part in causing these subjective phenomena.

The olfactory nerve is said to have been successfully stimulated by a galvanic current, but the painful nature of the experiment is a great hindrance to its success.

Sympathetic System.—In galvanizing the cervical sympathetic, the negative pole is preferred; it is to be placed just behind the angle of the lower jaw, and pressed with some firmness into the depression between the jaw and the sterno-mastoid muscle. The positive pole is put upon the nucha, or on the sternum, or even on the arch of the palate. The simultaneous application of the poles to the sympathetic of both right and left side requires caution, as liable to provoke giddiness.

The experiments made upon man by Eulenburg and Schmidt have proved that during the passage of a powerful galvanic current in this manner (the positive pole being upon the sternum), the pupil at the first moment enlarges to a very slight extent, and soon afterwards contracts. The change is so slight as to require the pupilloscope to demonstrate it. Under the same conditions, the pulse is observed to fall, after the current has been passing some time, from four to sixteen beats in the minute; the local arterial tension (carotid), and sometimes even that of the radial artery, are at the same time diminished. We have alluded to the local anæmia, and subsequent hyperæmia, attendant upon the practice of cutaneous faradization, and will add, that the effect may extend to the heart, which at first acts more rapidly, and then becomes retarded.

The secondary paresis of the sympathetic, with vascular dilatation, elevation of temperature, and increase of perspiration, is relied upon to explain many occurrences in physiology as well as in medicine. We will not go further into the discussion of a question, than which perhaps none has more puzzled the ingenuity of physiologists.

CHAPTER IV.

DIAGNOSIS.

Electricity is applied in various ways to test the functional activity of nerves and muscles. As used for this purpose, it may be classed with such auxiliaries as the sphygmograph, thermometer, plessimeter, and æsthesiometer; each instrument gives information of a certain order, which in some cases is sufficient by itself to establish a diagnosis, but in general must be considered as only one item in the total evidence. Electricity gives information in regard to two principal points: first, sensibility of skin, muscles, and some other parts; second, the function of motor nerves and muscles.

The electric brush or scourge has already been described. As a test of the cutaneous sense of pain it has this value, that the irritation may be made much more intense than that of ordinary methods, such as pinching or pricking; besides which, it inflicts no injury whatever upon the tissues. It furnishes a convenient agent for applying irritation, when we wish to provoke reflex contractions; it detects the "*points douloureux*" of affected nerves with more certainty than simple pressure (Neftel); for the latter purpose a very feeble current is sufficient.

The galvanic current applied to the spine will detect some conditions of deep-seated irritation or congestion. Pain is felt when the conductor touches the irritable

point, as is the case when a sponge dipped in hot water is passed down the spine; the pain of electricity is not necessarily evidence of the presence of inflammation, but is often felt at the tender spots of the so-called "irritable spine," in neuralgia or hysteria. Onimus and Legros consider this kind of tenderness an evidence of local congestion of the spinal cord.

The contraction of muscles under the stimulus of faradization is accompanied with a certain sensation; it is well to note whether this sensation is exaggerated or depressed, though no important diagnostic question may depend on the fact.

Tenderness of the sympathetic nerve is to be noted as a symptom of some irritative condition; pressure and the galvanic current (negative pole especially) produce pain at the point touched.

We have already spoken of the ear, and will here add that the sense of taste may be tested very conveniently by direct galvanization of the tongue with a weak current.

Sensitiveness to the electric current occurring in the track of a nerve, is an evidence that a neuralgia is not idiopathic. We expect to find some visible pathological condition, such as hyperæmia of the nerve, in these cases; hyperæsthesia or anæsthesia of the skin, and various motor disturbances, accompany this condition.

The main value of Electricity, as an aid to diagnosis, lies in the indications its reactions furnish with respect to the seat of a motor lesion. *If the lesion which causes paralysis is peripherally situated, the paralyzed motor nerve loses, wholly or in part, its power to respond to the electric stimulus; but if the lesion is confined to a central*

organ, to wit, the brain, medulla oblongata, or spinal cord, the "reaction" is not lost. If we find that a paralyzed nerve is deprived of its power of reacting under the stimulus of electricity, we infer that the lesion which causes the paralysis is seated peripherally. Whether, in such a case, a central organ is also affected, must remain a question to be decided upon other evidence; for the two classes of lesion may, of course, coexist. But if the nerve reacts well on the tenth day, we know that the lesion is not peripheral, and, therefore, must be central.

This rule being given, it is necessary to have a standard whereby we may determine whether the reaction is weakened; and, if weakened, to what extent this is the case. We have an extremely convenient standard for the purpose, when we are able to compare a paralyzed muscle with the corresponding healthy one of the other side. But if both legs, or both arms, are paralyzed, our estimate must be comparatively rough, there being no absolute standard, even for people of the same age and sex; it may be that the muscles of our patient were always sluggish under electrical stimulation, and that what appears a depressed condition is really the condition natural to the individual. But even if both sides are paralyzed, it is always well to compare them with each other, as there may be differences in the degree of implication. The following method may be used in the test.

Unless there is some special objection to doing so, some point in the median line of the body, as the spine or breast-bone, is taken for the application of one electrode. It should be large, and an assistant must hold it steadily. The operator takes the other electrode in one hand, and with the other hand regulates the current.

We will suppose that he is examining the condition of the right arm, and is testing the supinator longus. He ascertains by two or three trials the point of the muscle most favorable for producing contraction; he then fixes the electrode upon this point, while he graduates the battery to the minimum of force capable of producing visible contraction of the muscle. He notes the degree of force—indicated by the position of the damper-arrangements of the coil, whatever they may happen to be—and then performs the same operation upon the supinator longus of the left side. If the latter muscle requires less force to bring it to contraction, then one of two things is true: either the excitability in the muscle of the left side is excessive, or else it is depressed in the right side; and if the right side is the subject of a paralytic attack, we say generally that the paralyzed region has suffered a depression of its electro-contractility.

If the galvanic current is used, the operator holds the negative pole, as a rule; and in any case, the electrode in his hand should be rather small, with a button-tip, for the sake of exactness in localization. Both poles are to be kept well wetted.

It requires care and experience to apply these tests accurately. We will indicate some of the common sources of error:

1. Trying to produce vigorous contractions, instead of the minimum of visible contraction.

2. Unequal wetting of the two sides, which alters the relative conductivity.

3. When the galvanic current is used, neglecting to wait long enough for the reaction to develop fully; this requires half a minute or more, with repeated interruptions of the current.

4. Exhausting or irritating the part by too severe applications, such as voltaic alternatives.

5. In testing a nerve, the slightest deviation of the electrode from its position may make the test futile.

6. The limb should be placed at rest, and the muscle (generally) in a relaxed position. Both limbs should be placed in similar positions.

As a typical instance of peripheral lesion, let us take the case of a nerve which has been divided by a clean incision. Voluntary control of the muscle to which the nerve pertains is of course instantly lost. If a galvanic or faradic current is applied to the lower segment of nerve, the muscle responds promptly and well. On the second or third day, however, this response begins to grow weaker, and from about the eighth to the twelfth day it is completely extinct. The period of extinction may last very long; in fact, the nerve may recover its voluntary motor functions before it is able to respond to electricity.

If the shocks are applied directly to the paralyzed muscle, the same progressive loss of reaction is observed. But this is strictly true only of the faradic current. The galvanic affects the muscle differently, and rarely, if ever, wholly loses power to produce "direct" stimulation. But it frequently loses a part of its power, and it is not uncommon after a lapse of time to find the muscle very dull in its response to galvanism. And very frequently a phenomenon of apparently paradoxical nature is observed; about the middle of the second week we find that the "galvano-muscular reaction" begins to increase, and this increment may go to such an extent

that the muscle responds to a far weaker current than the corresponding healthy muscle.

When the paralyzed muscle acts under galvanic stimulus exclusively, it contracts with the peculiar, slow, long-continued movement which we have described as the "sluggish reaction."

These phenomena have been studied, both upon man and the lower animals, by numerous observers of the highest scientific ability, and the conclusions which we have stated may be considered as pretty nearly settled.

Cyon, however, has reported one isolated experiment,[1] which consisted in crushing the tibial nerve of a rabbit. At the end of ten or twelve days the nerve *retained* its excitability under the galvanic stimulus, but both nerve and muscle had completely lost the power to respond to the faradic shock, as well as to the very brief galvanic shock described on page 41. He says this is a unique case. Vulpian,[2] however, has observed the same phenomenon since Cyon made this observation. And I am told by my friend, Dr. J. J. Putnam, that he has once observed it in the peripheral affection of the peroneal and posterior tibial nerves which occurs in infantile palsy—the galvanic reaction of the nerve being certainly retained, and the faradic reaction apparently abolished at the close of several months after the onset of the attack.

In the human subject it rarely happens that a nerve is simply divided by a sharp instrument. It is, however, quite a common occurrence that pressure is exerted upon a nerve by extravasated blood, by a tumor, by a portion of callus, or by the presence of scrum or the

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[1] Principes d'Électro-thérapie, 1873, p. 248.

[2] Arch. de Physiologie, Nov. and Dec. 1873.

products of inflammation within the nerve-sheath. In other cases the nerve is injured by a blow or a gunshot wound, or is subjected to continued pressure from a hard object. In another class of cases extreme cold paralyzes a nerve; but we will leave this cause out of consideration for the present, as constituting matter of controversy; in all the other cases the same series of phenomena is observable, which we have described in connection with simple division of a nerve, only the lesion may be so slight or so partial as to produce an effect falling short in degree.

Other modes of destroying the nerves of animals have been practiced by various experimenters,[1] as compression with pincers or a ligature, or piercing with a needle dipped in acetic acid, solution of cantharides, or nitrate of silver. The result is not affected by the form of lesion, provided it be complete.

In all these cases the peripheral end of the nerve undergoes a degenerative process, resulting in a total disappearance of the axis cylinder, which is commonly regarded as the essential element in the transmission of motor impulses. The "central" stump also undergoes changes, of which we need not speak. But in regard to the peripheral end, we would briefly repeat the results of Ranvier's recent investigations[2] into the minute structure and pathology of the nerve-tube.

Ranvier has demonstrated that each nerve-tube is encircled by rings which properly belong to the sheath of

[1] Vulpian, Brown-Séquard, Ranvier; Gaz. Méd. de Paris, 1873, p. 304.

[2] Archives de Physiologie, 1872, No. 2; Gaz Méd. de Paris, 1873, p. 116; Comptes Rendus, 1873, lxxvi, 1, 491; Centralblatt, 1873, No 31.

Schwann; these rings divide the nerve into segments, the division extending through the myelin, but not into the central cylinder; half way between every two rings is observed a nucleus attached to the inner surface of the sheath, and completing the analogy between the "inter-annular segment" and a cell. In the process which takes place subsequent to the section of a nerve the nuclei, together with a layer of protoplasm, to which they belong, undergo hypertrophy; the axis cylinder (which appears to be passive during the process) is compressed, loses its continuity, and is finally absorbed. Ranvier states that the loss of continuity occurs towards the fourth day. He is of opinion that the changes he describes ought not to be considered as degenerative processes, but as due to an over-activity of the nutritive functions of the "cells"[1] when the regulative action of the central nervous system is withdrawn by solution of continuity.

Renewal of the nerve-tubes takes place after a period of time which is somewhat uncertain. Ranvier says that in his experiments "it may be best studied from sixty to ninety days after making the section." Schiff and Magnien, in similar experiments, have observed the *return of function* within seven and ten days, when the two ends were made to touch by suture; Vulpian has observed the same in seventeen days, but these are exceptional instances. Paget[2] reports two remarkable cases of division of the radial and median nerves by accident; the patients were boys, aged 11 and 13 years; and although no pains were taken to bring the cut ends into apposition, the functions of cutaneous sensibility began to return in ten or twelve days. We do not expect the

[1] "Cellules de la gaîne de Schwann," is Charcot's expression.

[2] Surg. Pathology, Amer. ed., 1854, p. 186.

motor function to be established as soon as that of sensation; in cases of division of motor nerves sixty days is a likelier period than ten or twenty.

In the practice of medicine we meet with frequent cases of palsy due to pressure, which may be of all degrees of severity. How severe they may be is well known to surgeons who have treated cases of arm-palsy due to pressure of the dislocated head of the humerus upon the axillary plexus. And how transitory may be the paralysis is shown by the experiment of Mitchell,[1] in which compression of the sciatic nerve of a rabbit by a column of twenty inches of mercury, produced total loss of conductive power, which lasted ten or fifteen seconds, and then gradually returned. The paralysis in this and similar instances seems to be due "to a mechanical disturbance of the nerve-fibres, which gave them for the time a baccated look and irregularities of outline, due to displacement of their semifluid contents," which disappears in a few days.[2]

Erb states that the impairment of electrical reaction within the first week corresponds to the degeneration of the nerves, including their intra-muscular terminations. The increase in galvanic reaction, when the current is applied directly to the muscle, is due (if present) to atrophic changes, attended with proliferation of nuclei within the muscle, while the subsequent fall in reaction in more chronic cases is occasioned by progressive atrophy supervening upon the acute stage. This explanation is the best we are able at present to offer. The phenomena themselves are, in rare instances, contradictory of all law, or apparently so, but that does not excuse us

[1] Injuries of Nerves, 1872, p. 113.

[2] Ibidem, p. 93.

from the duty of finding a solution. Erb[1] has proposed the name of "Entartungsreaction" for the whole of these changes in reaction which occur during the course of peripheral lesions. The term is a valuable one, and very expressive; it may be freely translated "reaction of altered tissue."

Brenner has examined the paralysis of motor nerves with much care, and has classified them in eight grades after a manner of his own, each grade being characterized by an alteration in the formulæ of Pflüger's law. Excess or diminution, or other alterations in the mode of reaction are observed, the most remarkable being that of the "fifth grade," in which the formula is reversed, so that muscular contraction occurs more readily at anodic closure than at cathodic closure; more readily at cathodic opening than at anodic opening. The sixth, seventh, and eighth grades are marked by the successive loss of AOZ, Ka OZ, and Ka SZ.[2] These modifications are not in the least imaginary, though it may not be possible as yet to connect each stage of modification with a corresponding stage of anatomical lesion; they deserve to be noted, and especially to be compared with the results of post-mortem examination.

So far we have traced the cause of the loss of electric reaction in cases of lesion of peripheral nerves. It remains to explain why the reaction is retained in central lesion, a fact most singular and striking, and almost savoring of the miraculous in the eyes of the vulgar. The explanation is the following:

[1] Op. cit., p. 368.

[2] For further developments see Brenner, op. cit., vol ii.

A nerve does not degenerate (unless itself hurt) as long as it remains in vital connection with the cerebro-spinal axis; and while undegenerate it is always capable of reacting, provided its muscle is in health, though it may be totally severed from the seat of intellect, and unable to receive the impressions of volition. The action of poisons is excluded from this statement.

It is not possible to give with absolute exactness the point at which this vital connection takes place, but we will assume for the present that the gray matter of the anterior cornua of the spinal cord, and the nuclei of origin of the cranial nerves, constitute such points. Intracranial lesions are, therefore, peripheral when they implicate the roots of nerves after leaving their nuclei of origin; and intraspinal lesions, affecting the roots of spinal nerves, are in the same category.

And first as to morbid conditions having their seat within the spinal canal. The simplest lesion likely to occur in practice is that caused by the pressure exercised by a tumor. Jaccoud[1] has formulated the law so clearly that we may adopt it in his own words:

"As far as the cerebral influence alone is withdrawn from the lower limbs, their reflex actions and electric motility, and the nutrition of their muscles, remain unimpaired; but when the spinal influence is cut off these properties are rapidly abolished."—"When the tumor occupies the lower extremity of the cord, or the cauda equina, reflex actions and electric movements are abolished within four or six days in the paralyzed parts, and the muscles at the same time begin to undergo atrophy." A glance at one's anatomy will show the reason

[1] Traité de Pathologie Interne, 3me éd., I, p. 373.

of this; pressure in that region must bear directly upon nerve-trunks, and thus shut them off from the influence of the central gray matter of the cord. But if the seat of pressure be a little higher, so that the lowest spinal nerves escape compression, the reflected movements and the electric reactions are exaggerated in all the muscles animated by the lower segment of the cord.

It is necessary to bear in mind the frequency with which inflammation of the substance of the cord complicates the effect of pressure, whether due to the presence of tumors, or to fractures, or to angular curvature of the vertebræ. In regard to these secondary changes: Myelitis,[1] whether acute or chronic, and sclerosis of the antero-lateral columns, leave the reflex function and the electric reactions intact, as long as the lesion simply interrupts the conduction of voluntary impulses, without destroying by a profound lesion of the central gray matter, or by disorganization of the roots, the proper and independent action of the spinal cord. Both reflex activity and electric reaction may be exaggerated, as has been stated in the case of tumors. If they are totally abolished, the fact is presumptive evidence in favor of myelitis rather than sclerosis; for "sclerosis is less apt to attack the *central* portions, and when it affects the *nerve-roots* it by no means constantly implicates the whole of them."

In sclerosis of the posterior columns (Progressive Locomotor Ataxia) it is usual to find the susceptibility of the muscles and nerves heightened in the early stages, but at a later period the contrary may be observed. The anatomical limitation of this lesion accounts for the re-

[1] Traité de Pathologie Interne, 3me éd., I, pp. 332, 346.

tention of reaction; and perhaps atrophy or sclerosis of muscular tissue may be assumed to be present in inveterate cases.

Acute spinal meningitis does not necessarily involve a loss of electric reaction, provided the medulla is intact. The same is to be said of hemorrhage into the vertebral canal; and yet the presence of the products of inflammation, or of a large quantity of fluid, *may* produce paralysis by pressure upon the spinal roots with the usual consequences. We would again remind the reader that the study of the reactions gives little direct information as to the nature of the morbid process in diseases of the spine, but may enable us to judge, to some extent, where the process is seated.

The "essential" paralysis of infancy is characterized by a rapid loss of both galvanic and faradic reaction in the paralyzed parts; and sometimes the galvanic reaction is obtained with a weaker current than usual. The disease, therefore, belongs to the class of peripheral palsies, and ought to be distinguished from cerebral palsies, which are not so very rare in childhood as to excuse the mistake of confounding the two classes. Cerebral palsy, as before stated, does not involve a loss of electrical reaction.

It is only recently that any satisfactory observations have been made to establish the locality of the original pathological process in infantile palsy. Without affirming that this question is absolutely settled, we would here refer to the results of autopsies made by Roger and Damaschino[1] in the cases of three children, who died of acute disease at the respective periods of two, six, and

[1] Gaz. Méd. de Paris, 41, 43, 45, 48, 51, 1873.

thirteen months after the beginning of the palsy. In these cases the enlargement of the spinal cord corresponding to the plexus supplying the paralyzed limbs was found diseased in its anterior cornua and antero-lateral columns; the diseased tract was one or two millimetres broad, and extended for quite a distance up and down. There was great proliferation of the nuclei of the cellular tissue, chiefly in the neighborhood of the blood-vessels; the lymph-sacs of the latter were full of granular corpuscles; the nerve-cells and the fibres of the anterior roots were atrophied. Sclerosis existed in the neighborhood of the older lesions.

Vulpian's[1] comment upon Damaschino's cases is favorable to the view which we here take. He says that the initial lesion is evidently situated in the cord, and is probably an inflammatory process affecting the gray substance, whereby the nerves are deprived of their nutritive centres in a few days. There is "a sort of destruction of the normal relations between the nervous cells and the fibres of the nerve-roots which take origin from them." The anterior roots were observed to contain a number of nerve-tubes; but this may have been due to autogenetic regeneration of the nerves, for we have as yet no autopsy of a case of recent origin.

Roth, of Basle,[2] describes and figures a case characterized by similar lesions of the anterior cornua. Cornil and Laborde speak of myelitis of the antero-lateral columns, as a cause.

We have dwelt at some length upon this point, as tending to elucidate the doubtful question as to the line

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[1] Gaz. Méd. de Paris, 1873, p. 9.

[2] Virchow's Archiv, vol. 58, part 2.

of division between peripheral and central lesions. It is evident enough that certain lesions in and near the anterior cornua involve destruction of a part or of the whole of the fibres which originate there, and that a lesion further back does not involve such destruction. We are not able to say precisely what these lesions must be in order to produce such an effect; this question must await its solution at the hands of pathologists.

In the case of glosso-labio-laryngeal paralysis, the difficulty seems greater. Kussmaul[1] considers this disease as essentially caused by atrophy of the ganglionic cells of the motor nuclei of the affected nerves, which may either be primary, or may depend on myelitis, leading to sclerosis, in the nuclei or their vicinity. The corresponding nerves are usually atrophied to a greater or less extent; the muscles are sometimes degenerated. Erb states that the electrical excitability of the paralyzed muscles commonly begins to fail after the disease has lasted some time. This statement cannot be raised to the dignity of a diagnostic principle; for it is certain that the reaction is often retained, and sometimes perfectly. Why this should be the case is not determined. It is, however, plain that the degeneration of the nerve-tubes, when it occurs, must involve a proportionate weakening of the muscular nutrition and reaction. It should be remembered that this disease may be simulated by primary muscular atrophy of the tongue, etc., in which the reaction of the muscle is perfectly retained.

Jaccoud[2] says that the alteration of the nuclei of the medulla oblongata produces abolition of the reflected

[1] Volkmann's Sammlung klinischer Vorträge, No. 54.

[2] Op. cit., pp. 401, 402.

movements, and of susceptibility to electricity, exactly as if the lesion concerned the trunk of the nerve after leaving the nuclei; that is, these functions are suppressed in proportion to the degree of destruction of nuclear tissue. And when the same nerves—those, namely, which are affected in glosso-labio-laryngeal paralysis—are attacked in their course *above the medulla*, in the pons, crura cerebri, corpora striata, and elsewhere, the paralysis affects the voluntary motor function from the first, but the electric and reflex contractions persist.

To this statement of Jaccoud we make a slight demurrer. Some lesions of the pons and the medulla oblongata are known to be followed by loss of faradic reaction. As a safer statement we here append Eulenburg's[1] summary:

"The inferences which we are entitled to draw from the electrical reaction, in respect to the location of a (cerebral) disease, are chiefly the following: If the susceptibility of the nerves to the faradic and galvanic stimuli is increased, the disease is seated centrally, wholly above the pons Varolii; if considerably depressed, or lost, under both classes of currents, the seat is wholly in or below the pons. An abnormally great susceptibility to galvanic currents, with loss of susceptibility to faradic currents, in the muscles of one side, speaks indirectly in favor of a peripheral origin of the palsy; and in connection with this, a pronounced atrophy of the muscles and other parts of the face furnishes another point in favor of the peripheral origin."

Two special peculiarities in reaction remain to be mentioned. They are appropriately introduced at this

[1] Lehrbuch der funct. Nervenkrankheiten, 1871, p. 521.

point because they are considered (by Benedikt) as characteristic of central lesion; though this is by no means exclusively the case. Sometimes the nerve acts well, but after a few shocks its power falls away rapidly while we are operating; the nerve is said to be "exhaustible." At other times the reaction increases with extraordinary rapidity while we are applying the current; this is the "convulsible reaction." The observer should bear in mind the possibility of these occurrences.

Benedikt affirms that affections of the pons Varolii are characterized by the presence of "crossed reflex action." This consists in muscular contractions, which occur in the paralyzed muscles when the healthy muscles of the other side are faradized; or *vice versa*, in the healthy muscles, when the paralyzed are faradized. There is a doubt as to the exactness of Benedikt's statement. One of his own cases looks very much against his theory, which, nevertheless, has a general correctness.

The "Diplegic Contractions" of Remak are certain reflex contractions of voluntary muscles, of rare occurrence, observed in various cases of atrophic and paralytic disease. They appear when the superior cervical ganglion of the sympathetic, or various parts of the spine, or the pit of the stomach, are stimulated by galvanic or faradic currents. They indicate an increased reflex excitability.

We will now speak of a few special applications of the foregoing principles.

Apoplexy, or more exactly, hemorrhage within the cerebral hemispheres, is frequently accompanied by a

slight increase of electric reaction in the paralyzed muscles. After some months have elapsed, secondary degeneration of the spinal cord may occur, with impairment of reaction. Yet it is common to see cases of cerebral palsy which have lasted many years without wasting or loss of electric contractility.

In Progressive Paralysis of the Insane, the electric reaction is not diminished for a long time; but in a few cases a striking "convulsibility" (abnormally strong reaction and quick exhaustion) was demonstrated by Simon.[1]

Writer's Cramp is said by Poore to be accompanied by a diminution of reaction in the cases examined by him. Paralysis agitans may present the same symptom. Certain local paralyses, attended by great derangement of the circulation in the parts affected, and lowering of temperature, are commonly ascribed to an affection of the sympathetic system; they may present this symptom in a very strongly marked degree. In Catalepsy, there is no uniform rule; retention and loss are both observed. In Hysteria, reaction is good at first, but if hysterical paralysis has lasted a long time, some diminution in reaction may occur (Althaus). Congestion of the Spinal Cord may involve impairment of reaction. These instances illustrate the fact, that a considerable variety of morbid conditions may produce a partial loss of electric reaction; it is sometimes hard to explain the phenomena, as, for instance, in catalepsy; and in the matter of diagnosis they are often unimportant.

Peripheral palsies from pressure, from rheumatic effusion, from the poison of lead, from acute eruptive fevers,

[1] Gehirnerweichung der Irren, 1871, p. 85.

from the lesion of infantile paralysis, are to be classed together as producing a set of changes characterized by the "Entartungs-reaction." Sciatic Neuralgia often presents the same anomalies; the reader will not need to be reminded that anæsthesia and partial loss of voluntary power also occur in this disease.

There is a class of paralyses of the arm in which it is doubtful whether pressure or cold is the efficient cause. The French have generally called these "rheumatic paralyses," or "*paralyses à frigore*," and have insisted on the absence of change in the reaction as a characteristic mark of the affection. They mostly occur during sleep, which makes it harder to determine their cause. "Radial paralysis" is the name given by the Germans. The pressure of the head, or some other hard article, upon the radialis (*i. e.*, musculo-spiral nerve) during sleep is generally sufficient to account for the symptoms; it is true that the reaction is scarcely ever quite abolished, though sometimes weakened. Panas[1] takes a similar view of the origin of this palsy. Vulpian[2] has reported a case of extensor paralysis occurring in sleep, and apparently due to cold, in which the faradic reaction of the radial nerve was found (by Duchenne himself) to be extinct at the period of fifty days after the accident. This is exactly one of the cases in which pressure *might* have been the true cause of the palsy, for the patient "awoke with his forearm under his head." But the exceptional point in the case consists in the fact, that the paralyzed *muscles* retained their faradic contractility perfectly for nearly two months. Vulpian ascribes the causation in this instance to the action of cold on the

[1] Arch. Gén., May, 1873.

[2] Gaz. Méd. de Paris, 1873, p. 183.

nerves at the point where they enter into intimate relations with the primitive muscular fibres. Webber[1] has discussed this matter very satisfactorily. Other eccentric phenomena are observed in a few instances of peripheral palsy, but the rules previously laid down hold good in most cases.

The facial nerve is frequently compressed and paralyzed by "rheumatic" exudation within the rigid walls of the Fallopian canal.

Paralysis from the pressure of crutches in the axilla[2] is not uniform in its features. Reactions of all sorts are sometimes good; often greatly weakened. Radial paralysis may result from this cause, as well as from dislocations and other injuries.

Duchenne has stated that paralysis of the extensors of the forearm, due to the poison of lead, spares the supinator muscles, while "paralysis à frigore" attacks them. His observation is correct in regard to lead palsy, and, generally, in regard to the other palsies, but Bernhardt[3] has published a case of paralysis due to dislocation of the shoulder, in which the supinators were intact in all their functions, while the other muscles of the forearm supplied by the radial nerve were profoundly affected. Lead-palsy is characterized by great, even total, insensibility to electric currents; it is similar to other peripheral palsies in this respect, but I doubt if the exaggerated galvanic reaction is often seen in lead-palsy. Loss of reaction, too, is often very decided before the patient notices much palsy.

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[1] Boston Med. and Surg. Journ., Dec. 18, 1873.

[2] Krafft-Ebing, in Deutsches Archiv, vol. ix, p. 123.

[3] Virchow's Archiv, vol. liv, p. 267.

Diphtherial Paralysis is shown by Oertel[1] to be due, at least in some cases, to hemorrhages; such extravasations occur in many central organs, and also among the roots of the spinal nerves, which are sometimes compressed, in the sheaths of the anterior and posterior roots, in the intervertebral ganglia, and in the sheaths of peripheral nerves. As yet, very few observations have been made. It was formerly considered (Meyer) that diphtherial paralysis never totally abolished the electric reaction; but a few cases have been lately observed, which have borne all the marks of peripheral palsy in their fullest extent, and careful observation will probably detect a frequent *diminution* of reaction. Of course, the presence of local hemorrhages fully accounts for this.

Variolæ and Typhoid Fever can produce the same class of palsies. Symptoms, however, may vary greatly, according to the seat of lesion; we have before stated that the electrical test informs us of the seat, not of the nature of the lesion. Westphal[2] has in one instance found disseminated spinal myelitis in variolæ.

Progressive Muscular Atrophy, when an independent disease, is probably of purely muscular origin. The wasted fibres of course cannot contract; but those not wasted retain their reaction, and extremely minute remnants of muscular tissue are capable of giving a reaction in proportion to their bulk. This fact is of great importance in enabling us to distinguish this affection from lead palsy, which is marked by a total loss, or a great diminution of reaction, before the atrophy has become pronounced.

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[1] Deutsches Archiv, vol. viii, p. 248.

[2] Berliner klin. Wochenschr., 1872, No. 42.

In Pseudo-hypertrophic Paralysis, the reaction is frequently depressed, but not always.

After death the muscles lose their power to contract, under electrical stimulation, in a few hours; and this may be turned to account in trances, when it is doubtful whether death has really occurred.

Palsy is sometimes simulated, for various reasons. But it is impossible to simulate the loss of electric reaction; the most resolute will cannot counterfeit the *passivity* which muscles commonly exhibit under faradization, in peripheral palsy; hence, by using the battery, we may sometimes be able to refute the charge of malingering, and to affirm that the palsy has a substantial existence.

CHAPTER V.

METHODS OF APPLYING ELECTRICITY.

For the practical details of the application of the faradic current we are indebted almost exclusively to Duchenne. The physician should make himself well acquainted with the "*points d'élection*," which are given in the following diagrams. He may thus spare his patients much annoyance. These points, which are the most advantageous for producing given muscular contractions, are tolerably constant; as much so, certainly, as the distribution of the motor nerves, for they correspond exactly to the places where these nerves enter the muscular tissue. For the demonstration of this fact we are indebted to Ziemssen.

In the accompanying illustrations, the motor points have been placed as given by Ziemssen, with a very few exceptions in the case of the full-length figure, where, for instance, I have given two points for the sartorius. The reader will observe the position of the arms in the same figure; the right forearm presents its anterior aspect, but is very slightly pronated, so as to show a little of the swell of the extensor muscles on the radial edge of the arm. Here the points for five or six muscles lie almost in a straight line up and down the arm. The left forearm is so foreshortened that only a few points could be fixed; but this and other deficiencies have been supplied in the smaller illustrations. (Figs. 13–16.)

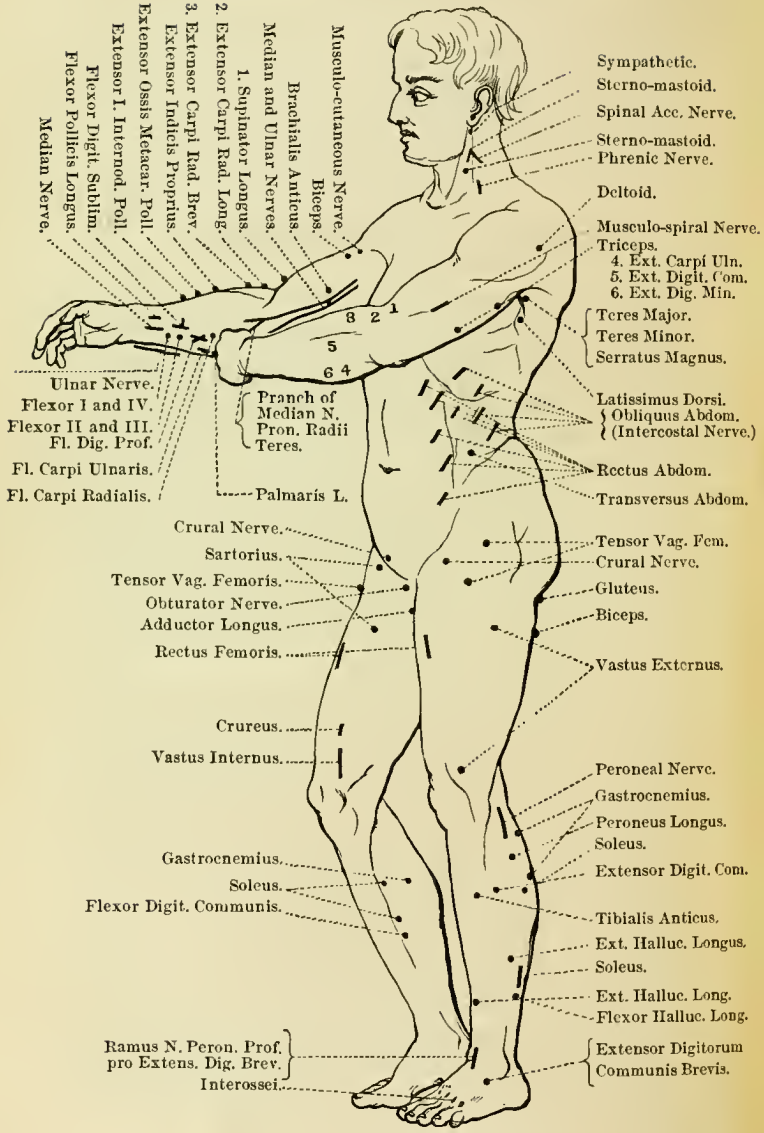


FIG. 12.—MOTOR POINTS OF TRUNK AND LIMBS.

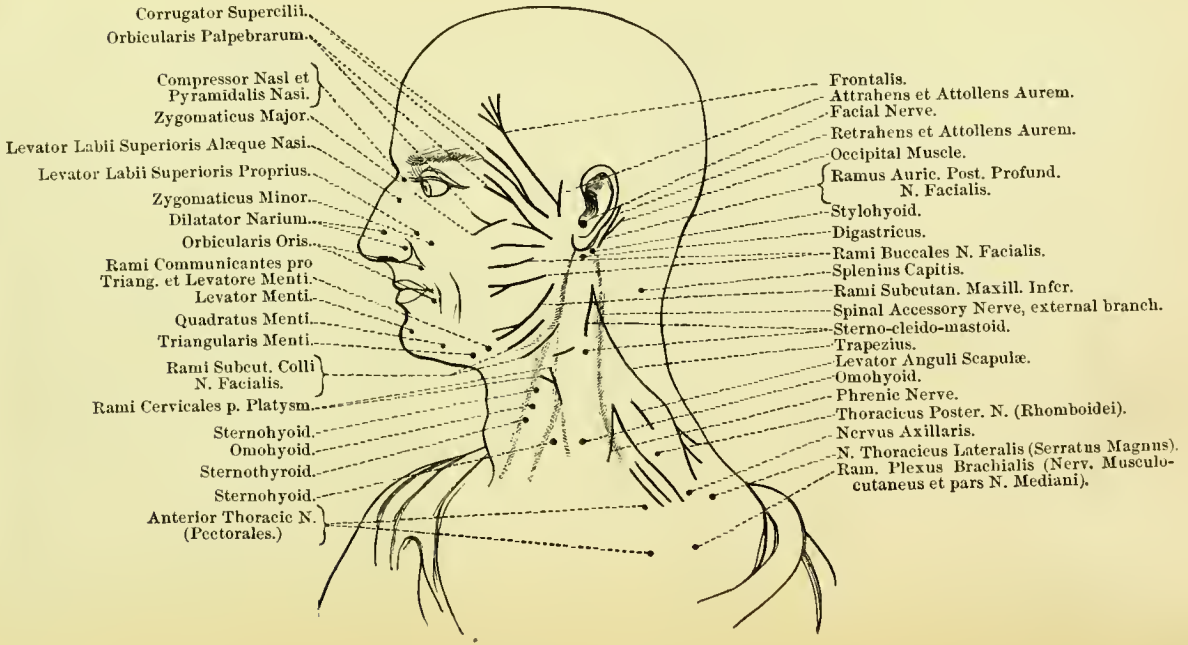
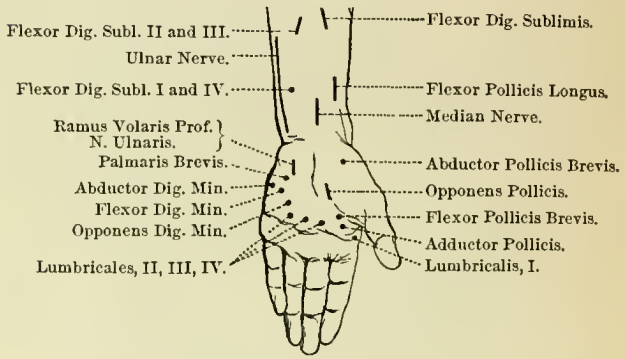


FIG. 13.—MOTOR POINTS OF FACE AND NECK.

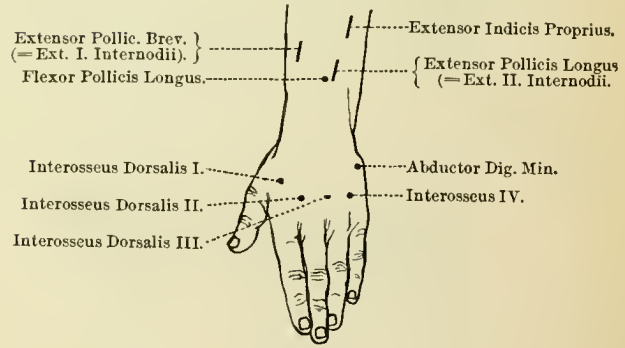
The position of the motor points is subject to more or less variation, owing to individual peculiarities of anatomy.

FIG. 14.



FRONT OF HAND.

FIG. 15.

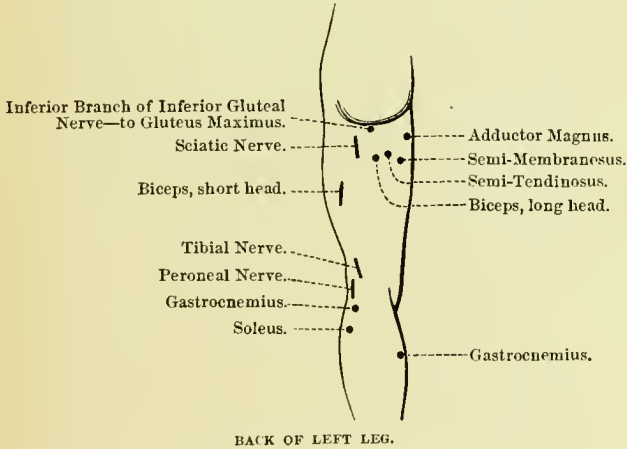


BACK OF HAND.

Both poles of a faradic apparatus will produce muscu-

lar contraction; that caused by the negative pole is the stronger. A very convenient method, where many muscles are to be stimulated, consists in placing the positive pole in connection with a large metal plate, upon which the patient sits, or places his feet. The negative is then applied at the operator's will. This plan does not stimulate the gluteal muscles to any perceptible extent, unless powerful currents are used; there can be no objection to its employment in ordinary cases, unless it be especially necessary to avoid stimulating the menstrual function; and in the latter case we should avoid the electrical stimulus in almost all its forms. In general it

FIG. 16.



BACK OF LEFT LEG.

is better to have both poles in simultaneous use in the operator's hands. Less powerful currents are required when the poles are placed near together.

"*General faradization*" consists in stimulating all the

muscles of the body in rapid succession. It has been recommended to use the physician's own hand as an electrode in the following manner: The patient sits or stands upon the plate, connected as above with the positive pole. The negative pole is attached to a sponge grasped in the operator's left hand, while with his right hand, well wetted, he touches the points to be affected. Thus the path of the current lies through his own body, and the muscles of his own arms are forced into involuntary, sometimes painful contraction. I have heard from the lips of one of the gentlemen who propose this method (Messrs. Beard and Rockwell) quite vivid descriptions of the fatigue they have experienced from this self-sacrificing practice. There is no doubt that the human hand is an admirable electrode, yet it can hardly be necessary to resort to this method unless we desire to pass a current of extreme delicacy through so sensitive a region as the skin of the forehead, or the eyelid. In such a case the following modification of the plan may be used if we choose: the patient may hold the positive pole in one hand; the operator wets his own hand thoroughly, lays it carefully on the forehead, cheek, or neck, graduates the battery to a point of low intensity, and applies the negative pole to the back of his own hand, as it lies upon the patient's skin. The patient's skin, not his clothing, should come in contact with the conductor; but a stocking will generally be damp enough to permit the passage of a faradic current when the feet are placed on the metal plate as above described.

The "*central galvanization*" of Messrs. Beard and Rockwell is performed by placing the negative pole upon the epigastrium, while the positive is applied at the top of the head, over the region of the pneumogastric and

the cervical sympathetic in the neck, and down the entire length of the spine.

Clemens, of Frankfort,[1] has a method called the "*unipolar*," which, as he considers, possesses a power to quiet spasm and allay pain, and in general to exert a soothing influence upon the system, which is desirable in the initial stages of chronic diseases of the spinal cord. His patient's feet are placed on a thin bit of wood resting on the metal plate already described, the plate being in connection with the negative pole of a powerful faradic apparatus, while the positive is applied to the spine in the neck. He says that the whole body thus becomes charged with electricity of high tension. If this were true, the arrangement would be only an imperfect substitute for Franklin's rotation machine and the Leyden jar. It is, perhaps, to be feared that the wooden disk separating the feet from the metal disk may retain a certain degree of moisture, which makes it form an actual conductor, in which case the current would be no more "unipolar" than any ordinary current.

A ready method of moderating the faradic current is proposed by Ducheune. He lays a long strip of wetted cloth on a table; one pole of the battery is connected with one end of this strip, while from the other end proceeds another wire carrying an ordinary electrode. Thus the path of the current lies through the water, and we can lessen the resistance at will by diminishing the length of cloth traversed by the current.

The applications of *static electricity* are described elsewhere (page 125).

The *electric bath* is arranged by placing the patient in a tub of water, supporting him by blocks of wood, and

[1] Deutsche Klinik, 1872, No. 52, et seq.

causing a faradic (or galvanic) current to traverse the water (which it does with facility) in such directions that the body, or a portion of it, may receive its direct influence. Thus the whole surface of a body or a limb receives the impression, and there is not sufficient concentration at any point to produce muscular contractions. Hence the result is entirely different from ordinary faradization. The electric bath, in brief, is a refreshing stimulus to the cutaneous surface, and must possess general tonic virtues scarcely different in kind from those of hot spring baths, especially those which are charged with carbonic acid.

For purely local applications, when we desire to affect a joint or a limb, without much reference to the individual muscles, it is convenient to plunge the part into a basin of water; one electrode is put in the water, and the other is applied upon some neighboring part of the body. A pair of large sponge electrodes answers the same purpose.

The electric brush, or scourge, composed of a bundle of fine wires, is drawn lightly and rapidly over the skin, which ought previously to be well dried. The sensations are extremely painful. When the brush is held continuously over one spot we have the "electric moxa" of Duchenne. A similar stimulation may be furnished by the button-shaped electrode of naked metal. This is attached to the negative pole of a faradic apparatus, the positive being connected with a large and well-moistened electrode, which may be placed upon any indifferent portion of the body.

The negative galvanic current, applied to the skin by a naked metallic rheophore, furnishes a species of potential cautery, which has been recommended as a revulsant

in obstinate sciatica. It is very painful, and the sores heal slowly.

In the use of the *galvanic* current we are obliged to pay particular attention, 1, to the points of application; 2, to the direction in which the current flows; 3, to the fact of interruption or non-interruption of the current; 4, to the number of cells used.

1. The *points d'élection*, if we desire to produce muscular contractions, are the same as in the case of faradism. For this purpose we adopt the following procedure. The positive is to be applied over the course of the nerve, or upon the plexus whence the nerve originates, or upon the vertebral column at the origin of the plexus; or, if the physician desires to confine the action to the muscle, upon the body of the muscle. The negative pole is placed upon the "motor point" of the muscle.

In galvanizing the spine, one pole is commonly placed on the back of the neck, and the other at some lower point, or upon the sacrum. The region of the first two dorsal vertebræ, and that of the lumbar vertebræ are important, as containing the cilio-spinal and genito-spinal centres.

The point for the cervical sympathetic is in the depression between the angle of the lower jaw and the sterno-mastoid muscle. This corresponds with the superior cervical ganglion. One pole being placed here, the other is put on the back of the neck—or on the upper part of the sternum—or (less frequently) upon the region of the superior ganglion of the other side.

Cyon has called attention to the importance of gal-

vanizing the spinal cord at the points where the sympathetic filaments for the limbs are given off.

The roots of the spinal nerves can be influenced most directly, if we put long narrow electrodes upon the muscular region just to the right and left of the vertebral spinous processes, pressing the instruments firmly in upon the tissues.

Galvanization of the ear is elsewhere described. The retina may be reached by placing one pole on the closed eyelid, the other on the nape of the neck. The gustatory nerves are best reached by pressing both electrodes just below the lower jaw; or the tongue may be stimulated by direct application. The pneumogastric is affected by placing the negative pole on the carotid artery near the angle of the jaw, and the positive on the sternum.

2. The current is supposed in all cases to travel from the positive to the negative pole. When the positive lies nearer the central organ (brain or spinal cord), and the negative is nearer the periphery (muscular, cutaneous, and visceral distributions), the current is said to be *descending*. Such is the case when the positive pole is upon the spine, and the negative upon a plexus, muscle, or nerve; or the positive on a plexus or nerve, and the negative on a muscle. When the order is reversed, the current is said to *ascend*.

In the case of an isolated nerve, prepared for the experiment, the current can be made to travel in the route we intend for it. But when the nerve lies imbedded in the living tissue at an uncertain distance from the surface, and surrounded by other important nerves and organs, we may place the two poles upon two points in the course of that nerve, but we cannot expect to get results

quite coincident with those of the laboratory; the current goes in the general direction intended, and a good deal of it goes through the nerve in the direction intended; but a good deal besides enters and leaves the nerve at all points of its course, as might be expected when the surrounding tissues are nearly as good conductors as the nerve itself. Nevertheless, there are places where the nerve runs very near the surface, and where the facts of electrotonus have been demonstrated in the living human arm. Such facts justify us in attaching a degree of importance to the selection of the pole to be used, which is denied by many writers, among whom we may mention MM. Onimus and Legros. These writers attach a great, and perhaps a deserved importance to the *direction* of the current; their rejection of the *polar* distinction does not appear justified by the facts of science and the tendencies of therapeutics. As elsewhere remarked, the distinct action of the anode and the cathode is proved most palpably in the case of motor nerves, and is applicable with much probability to nerves of sense and the sympathetic system. In general, the positive pole produces sedation, the negative stimulation, when the current is kept steady and unbroken.

3. The distinction between a galvanic current kept at a steady height, and one which is interrupted, is of great importance. If the sedative effect is ever to be obtained, it must be through much care in this respect; the electrode must be held steadily by the hand of a proper person, and if possible not shifted from place to place. A powerful current may be introduced gradually by means of the rheostat, without causing any shock.

The term "stabile galvanization" is employed to denote that the electrodes are not moved about. The con-

trary is expressed by the adjective "labile;" in this method one pole is usually kept fixed, while the other is stroked over the region to be affected. Althaus uses the epithets "continuative" and "intermittent galvanization" in the same senses. In labile galvanization the strength of the current and its distribution vary from moment to moment; the skin is quickly reddened, and pain may be severely felt; as to the subjacent parts, they receive a powerful excitation, muscular contraction in particular being often noticed. Interruption of a galvanic current produces a still more active stimulation. A downward current is perhaps the more commonly used. Reversal of a galvanic current is the most powerful form of stimulus, and should not be performed upon the head or neck without weighing the risks.

4. As regards the construction of batteries, it is well to avoid those in which the individual cells are very powerful. For portable apparatus we cannot apply this rule, for most of the good portable batteries have a more powerful chemical action than is exactly desirable; this seems to be best avoided in the Beetz-Leclanché battery.

CHAPTER VI.

MEDICAL AND SURGICAL PRACTICE.

It has been thought best, in describing the therapeutic results of electricity, to omit descriptions of individual cases, of which great numbers are recorded in the larger treatises. The value of such descriptions is incontestable; but it seems to the author that the space at our disposal can be best employed by grouping the diseases into classes, and explaining the general principles applicable to the treatment of each class.

First of all, however, let us take a synoptical view of the principal therapeutical results which we may expect from the use of electricity.

1. Stimulation of the Functions of Muscles, both striped and unstriped, and of all muscular organs.

2. Stimulation of the Trunks of Nerves, both Motor and Sensory.

3. Stimulation of the Cutaneous Nerves of Common Sensation.

4. Stimulation of the Organs of Special Sense.

5. Stimulation of the Secretions, as the saliva, tears, and milk.

6. Stimulation or Regulation of the Vaso-motor System, with relief to irregularities of temperature, etc., and to several special conditions, as Graves's disease.

7. Dispersal or Absorption of Fluid in tissues, joint-cavities, bursæ, etc.

8. Improvement of Nutrition in paralyzed organs, in chronically inflamed joints, nerves, and other tissues.

9. Acceleration of Metamorphosis of Tissue.

10. Relief to Pain.

11. Relief to Fatigue; communication of a sense of vigor.

12. Relief to Spasm.

13. Relief to Insomnia, and a variety of irregularities in the cerebral and spinal functions; to which add "Hysteria."

14. Destruction of Morbid Tissues by the chemical action of galvanism, or by actual electric cautery.

In regard to the comparative action of the two classes of currents, we will simply say that each of them is more or less applicable in all of the above instances, except No. 3, in which "cutaneous faradization" is far better than galvanization; 4, in which faradization is proscribed by many authorities; 6 and 10, in which galvanism has the preference. And in the other cases, it would not be just to say that the selection of one or the other current was a matter of indifference, for a great many circumstances are capable of influencing our choice, and there is almost always some reason for preferring one to the other.

Duchenne attaches great importance to the distinction between the currents from the primary and the secondary coils. His general conclusions are as follows; they are applicable to coils constructed in his manner, as described on page 35:

"The current of the first helix excites most acutely the sensibility of certain subcutaneous organs; the nerves, the muscles (proportionately increasing their contractility), the rectum, the bladder, the testes, the epididymis, and the spermatic cord.

"The current of the second helix acts most powerfully upon the cutaneous sensibility, upon the sensibility of the retina, and penetrates most deeply into the tissues."[1]

Is the therapeutic action of electricity always that of a stimulus? It is not possible to answer. In some cases a strong dose overexcites, while a weak dose quiets. Is this latter effect an instance of the sedative action of electricity? In response to this question I take the liberty of quoting the expressions of Hitzig,[2] which are extremely judicious and to the point.

"If you ask me how the action of electricity in nervous diseases is to be explained, I can only reply that this problem cannot receive a general solution until we shall have gained more accurate insight into the nature of the processes of disease. This is the end, to the attainment of which, as I think, all our efforts ought to be combined. Until we reach this end, we are only entitled to regard electricity as a stimulus, though it be a stimulus capable of innumerable modifications in degree and kind. The discovery of these modifications, up to the present time, has constituted an art and not a science."

We will now attend to the special applications of electricity.

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[1] Localized Electrization, translated by Tibbits, page 27.

[2] Address before the Versammlung der Naturforscher u. Aerzte, Leipzig. Berliner klin. Wochenschrift, 40, 1872.

A. Organic Central Lesions.

In the treatment of all diseases caused by degenerative processes in the central nervous organs, the galvanic current, assisted sometimes by the faradic, is of leading importance.

The properties of the galvanic current, upon which we chiefly depend to explain its known therapeutic action upon the nervous centres, are principally two: its power to improve local nutrition, and its power to hasten the absorption of morbid material. Both these processes are dependent to a considerable extent upon the improved activity of the vaso-motor system.

Remak employed the term "catalytic action" to express a compound result, derived partly from the influence which galvanization is known to exercise upon the circulation and nutrition of organs through which it passes, and partly from certain purely physical processes, to wit: endosmosis and electrolysis. It is well known that the particles of a fluid traversed by the current are carried (electrovection) with more or less force from the positive towards the negative pole, as may readily be seen in experiments with colored liquids. It is also quite certain that chemical processes of various sorts go on in the fluids of the body while the electric fluid is passing through them. Such processes are most prominent at the point of external application of the electrodes; and if the tissues situated between the points of application constituted one mass of chemically homogeneous substance, the action would be limited to those two points of entrance and exit. But the intervening tissues are not homogeneous; and hence there must be a

slight chemical action going on within their substance as a result of the electric force. We will not attempt to speak of this class of reactions; as to those occurring on the surface, they have been already described.

There is no reason to doubt that the spinal cord and the brain can be made to receive a large charge of galvanism. What happens to the nervous tissues in this case is a matter of inference, but of very rational and easy inference. The circulation is unavoidably affected. The thoracic ganglia of the sympathetic lie nearly in the direct line of the current, when applied to the spine, one pole resting on the back of the neck and the other on the lumbar vertebræ or the sacrum. And as to the capacity of the electric current to affect the processes of resorption, we have abundant evidence in the success which attends the electrization of tumors and rheumatic swellings by the cutaneous[1] method. These results are probably under the control, in great measure, of the nervous system.

It is probable that both orders of the current act alike, to a certain extent. Faradism, however, has a minimum of chemical action. On the other hand, galvanism, when applied to muscles, affects the central nervous system much less than do the painful shocks of powerful induced currents. Both currents possess the remarkable property of refreshing muscular or nervous tissue; of removing the sense of fatigue, and increasing the ca-

[1] The author would recommend the application of the word "cutaneous" to those cases in which the skin is not pierced, as in "cutaneous faradization" (Duchenne) and "cutaneous cauterization" (Victor v. Bruns). "Percutaneous" is an ambiguous term; it ought perhaps to be made equivalent to "subcutaneous," implying the piercing of the skin by needles (as in the "percutaneous or parenchymatous cauterization" of v. Bruns).

pacity for responding to stimuli. These facts, which remind us strongly of the action of warm baths upon the system, may be explained as the reader chooses; it is not certain how much influence the purely chemical functions of the current possess. Galvanism is almost universally declared to be the only suitable form of direct application to the nervous centres; this, too, is an empirical law, based on the observed facts of injury to the nervous system, resulting from too severe shocks of faradic electricity. In laying down this law, let us not forget for a moment that galvanism, if abruptly interrupted, or reversed, or made too powerful, is also capable of causing a severe "shock to the nervous system."

Acute morbid processes, attended with elevation of the bodily temperature, forbid the employment of electricity. But sclerosis, and chronic spinal meningitis, and myclitis, are fit subjects for direct galvanic treatment of the spinal cord and brain, to which should be added, in some cases, the electrical stimulation of the muscles. We offer no opinion as to the prospect of recovery in meningitis or myclitis, though convinced that the prospect will be improved by the use of galvanism.

Locomotor ataxia presents a fair object for galvanic treatment. Most authors who have written upon the subject are agreed upon this. Benedikt is quite sanguine, and says that a protracted perseverance in treatment is necessary. Krafft-Ebing[1] has reported the complete cure of a very few recent cases, bearing the distinct marks of the disease. He says that the application of the constant current is capable of producing not only single radical *cures*, but such distinct, permanent *im-*

[1] Deutsches Archiv für klin. Medicin, ix, p. 274, 1872.

provement of old cases that the curability of the disease —at least in the commencement—is beyond a doubt. It never does harm, according to him; six or eight sessions are enough to show if any good results are to be expected; the current is applied through large conductors to the sacrum and the supposed upper limit of the lesion, and a very strong current is passed (either upward or downward) for four, five, or six minutes.

Glosso-labio-laryngeal paralysis is decidedly a proper object for galvanic and faradic treatment, which frequently produces an unquestionable, even a surprising improvement, though unfortunately the latter is only transitory.[1] Cure is not obtained. The current (galvanic) is localized in the various paralyzed regions by applying the negative pole and interrupting the current; or else by stroking with the negative pole; while the positive is to be placed on the back of the neck, near the seat of primary lesion. Faradism is applied directly to the muscles.

In Cerebral Hemorrhage, Embolism, and Thrombosis, some of the best authorities at present justify or advise the practice of galvanizing the brain by passing the current directly through it, as early as a week after the attack. It is of course presupposed that this is done with great care, and that only the galvanic current, in moderation, is used.

Cyon has recently attacked the practice of cerebral galvanization, upon the ground that, at the best, the only therapeutic result will be a stimulation or irritation of the brain; that the current cannot be kept so steady as to avoid all shock; and that it is impossible to local-

[1] See A. Kussmaul, in Volkmann's Sammlung, No. 54.

ize the current in the seat of disease within the skull, even if we suppose that we know the seat.

One can readily see the propriety of such objections, in cases where irritative symptoms supervene upon cerebral hemorrhage. But granting the correctness of his physical statements, it seems to me a narrow view that excludes a method of treatment because it is of the nature of a stimulant. Stimulants are not necessarily excluded in the treatment of "apoplexy;" alcohol is not excluded. It is bad logic to employ the term "irritation;" the word implies, not *stimulation* simply, but *over-stimulation, injurious* stimulation; and the question as to the injury or benefit derived from galvanism is in these cases a clinical question, not a physiological. As such, I freely admit that the matter has not been sufficiently tested as yet. And in further justification of our right to go on with the present treatment, I would only recall what has already been said regarding the power of electricity to stimulate nutritive and circulatory processes in all the tissues.

At the period of a week, or of a few weeks, after the attack of cerebral palsy, it becomes necessary to decide whether the electric stimulus shall be applied for the relief of *local* symptoms of paralysis or contraction.

Upon this point, we will first cite the directions given by Reynolds.[1]

1. During the condition of shock, with anæsthesia, which exists for a few hours or days after the onset of hemiplegia from embolism or hemorrhage, we must not use electricity. After the shock has passed away, the electric brush may be used to relieve anæsthesia.

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[1] Lectures on the Clinical Uses of Electricity.

2. In those cases of acute cerebral disease in which you find persistent anæsthesia, or diminished sensibility, it is very rare to find that electricity does any good. It may do harm.

3. If cerebral paralysis comes on gradually, with pain in the head, weight of the head, or giddiness, electrical treatment must be postponed for a time.

4. Electricity may do harm in early rigidity, after cerebral paralysis.

5. If these symptoms of cerebral irritation are absent, it is still proper to wait "some little time" before using electricity.

As to the length of time that it is necessary to wait before applying faradic currents to the limbs, that is a matter upon which opinions differ. It is common to say that we must postpone the operation for three months. Onimus and Legros are in the habit of applying galvanism to the head, a week after the occurrence of cerebral hemorrhage; and faradism to the limbs, after from thirty to fifty days, at a period when they presume that the clot is reabsorbed and the limiting membrane formed. Hammond[1] says that "in about two weeks it will be proper, in the majority of cases, to take active measures to restore the power of motion, and to prevent those contractions which tend to make a restoration much more difficult." Althaus advises to begin to use central galvanization when two or three months have elapsed since the attack; and faradism may be employed, later, for the limbs. M. Rosenthal directs us to commence electric treatment in two months in light cases; in the severe we should wait till symptoms of

[1] Nervous Diseases, p. 110.

irritation are past. Duchenne has treated a considerable number of patients by faradism, applied to the muscles, very soon after the attack of cerebral hemorrhage; he observed no benefit from this early treatment, and has come to the conclusion that we ought to wait from six to ten months! If we then commence, and find that fifteen or twenty applications do not improve the patient's muscular power, he would advise us to take the fact as proof that the brain has not yet sufficiently recovered to permit the resumption of its functions; we should then wait, and recommence treatment at a later period. He gives emphatic warning against faradizing the face, and with his usual candor he gives a case of his own to illustrate the mishaps that he warns against. The patient in question had had several cerebral hemorrhages; at the time of treatment she had been paralyzed two years and a half; he faradized her *tongue* "*avec assez d'énergie*," and another hemorrhage occurred while he was engaged in the operation.

Hemorrhage is, naturally, the principal danger to be avoided. But it is very questionable whether we shall avoid it by merely postponing our action any given number of months. If disease has weakened one artery so that it has been ruptured by an excess of pressure, it is likely that other arteries are also diseased, and we cannot say how soon some other point will be broken through by a similar excess of pressure. It should be our aim, therefore, first to wait long enough for the clot to become firm, that the arteries may be occluded at the point of rupture; and next, to employ remedies in such a manner as not to increase the blood-pressure within the brain.

As to the first point, firm occlusion of small arteries

requires very few days if the clot has not been disturbed. This requires no proof; it is matter of common surgical observation. There seems to be no reason why clots should not form and set in the cerebral vessels as readily as in those of the limbs. Besides, the artery or aneurism is in all probability quite small, or even minute, if the patient survives the bursting of it.

As to the second point, it is important to avoid giving pain. Faradization of the surface of the skin, a very painful operation, acts with great certainty in increasing the tension of the arterial system. Duchenne gives a rational caution against the use of too rapidly interrupted currents; he frequently employs intermissions at the rate of only one or two in a second, with the object of avoiding pain. It is further to be observed that it is totally unnecessary to produce powerful contractions of the muscles; if they are made to move visibly, that is sufficient. Violent treatment is capable of aggravating the contractures, and of producing various other symptoms of cerebral irritation, such as sleeplessness; and it may become necessary to pause in the midst of the electric treatment in order to combat such symptoms.

As regards the probability of restoring power to the muscles, Reynolds says that electricity will do good in those cases in which the power to react has been partially lost; if the reaction in the paralyzed muscles is normal, as compared with the muscles of the healthy limb, we need expect no benefit, except that we may lessen the atrophy which sometimes occurs, and may relieve chronic rigidity of certain muscles. He points out the indirect effect which treatment of the muscles may exert in improving the nutrition of the brain or spinal cord.

Galvanization of the brain has been attended by rapid improvement in recent cases of cerebral hemorrhage, in which no other remedies were used. In old cases it is said to have produced instant and great improvement in muscular power. In both cases authorities warrant us in using it.

Infantile paralysis, strictly so called, is generally amenable to the influence of electricity if seen within a few months of the attack. It is important to use the interrupted galvanic current of a strength just sufficient to produce muscular contractions, more especially if the galvano-muscular reaction is found to be heightened. The spinal cord should also be galvanized. At a late period, when the paralyzed muscles have become atrophied, deformities may arise, of which the prognosis is generally favorable. If faradism then makes the paralyzed muscles contract well there is great hope of improvement; and even if the current fails to produce any visible contractions, it is not necessary to infer the absolute incurability of the case, although great doubts may be entertained. In these cases of inveterate palsy with atrophy, a very protracted treatment may be required, lasting from one to three years.

These statements are not applicable to hemiplegia, which sometimes occurs in children, and is to be treated like the same affection in adults. Children sometimes feel the galvanic shocks very painfully, but may easily be faradized if caution and tact are used.

B. Organic Peripheral Lesions.

The anatomical changes in the nerve-tube which has been subjected to pressure, or divided, or otherwise in-

jured, have been described in a previous chapter. The following may be enumerated among a great variety of causes capable of giving rise to peripheral paralysis:

Pressure, exercised by exostoses and other morbid growths, by callus, by aneurisms; by the fœtal head pressing upon the nerves of the pelvis; by the forceps, or the accoucheur's finger, upon various parts of the child; by crutches, upon the axillary plexus; by heavy burdens, straps, or cords, or the snaffle-rein of a bridle; by any sharp edge, as of a chair or table over which a limb is allowed to hang; by various false positions of the limbs in waking or sleeping; by a variety of morbid products within the sheath of a nerve, such as are found in paralysis consecutive to acute fevers.

The "rheumatic" lesion of nerve-trunks; a term which properly implies the presence of an exudation within the sheath of a nerve, but which has been erroneously applied to certain lesions from simple pressure. The influence of extreme cold upon superficial nerves is also loosely called "rheumatic."

Concussion, tearing, stretching, or cutting of nerves and plexuses, by dislocations, fractures, contusions, and gunshot and other wounds.

In all these cases electricity, applied directly to the muscles and nerves, is likely to be of service; it ought, when possible, to be associated with *massage* and local gymnastics, but these latter, and indeed all other items of treatment, are subsidiary to electricity. It cannot be doubted that, except in the mildest cases, the voluntary functions of the muscles are recovered much more rapidly when electricity is used than when it is omitted; and with them the general nutrition of the parts is much improved. Whichever current makes the muscles contract

best is the one to be preferred. Faradism answers most purposes, but galvanism is required if the muscle reacts with unusual readiness to the latter class of currents. Mitchell,[1] whose words we have just been employing, advises the use of a local hot bath just before each application of electricity; this, he says, increases the muscular irritability very perceptibly, and so does the operation called *massage*. I have found a hot-air bath useful in the same way.

All these paralyses obey the law in accordance with which severe or destructive lesions of nerves, plexuses, and roots entail the loss of electric reaction. Lesions of moderate severity simply impair this function in varying degrees. A sleeping person's head may repose upon the outside of his arm in such a way that the musculospiral nerve is compressed against the humerus; he awakes with a paralysis of the extensors of the forearm; in a week or so we apply the faradic test, and are able to estimate the gravity of the lesion, and the prospect of recovery, by observing the degree to which contractility is impaired.

Dislocations, especially of the shoulder, are often the cause of a local paralysis, which seems to be distributed with little uniformity among the muscles affected, some of the latter retaining their reaction, while others lose it. Often, too, a muscle slightly paralyzed recovers after a very few applications, while its neighbor requires many months of treatment with very powerful currents. Treatment of a muscle which gives no response is not only permissible, but is often rewarded by entire success. Only one circumstance would justify us in giving an

[1] Injuries of Nerves, and their Consequences, 1872, chap. xi.

absolutely unfavorable prognosis, and that would be the knowledge that a given muscle was entirely atrophied; this we are not able to affirm, even when the muscle is entirely inert (to appearance) under powerful stimulation. This absence of reaction, however, especially when conjoined with an impairment of the perception of the pain of the application, in cases of several years' standing, leave very little hope of improvement.

Fractures, sprains, rheumatic inflammations, and other diseases for which rest of the limb is prescribed, sometimes leave the muscles in an extremely debilitated condition, which is apt to be greatly and speedily benefited by the faradic stimulus.

Paralyses from gunshot injuries of nerves are to be treated like other peripheral paralyses. It is well to note that the author to whom we owe the best account of these lesions advises the use of the faradic or galvanic current from the earliest date at which the healing of the wound allows of their use.[1]

Meyer[2] has published a *résumé* of a large number of cases of disability of the limbs, arising from the presence of cicatrices, anchyloses, and contractures, following gunshot wounds. He applies the positive pole of the *galvanic* battery to the cicatricial tissue, or the contracted muscle, and the negative to some other portion of the limb; the applications are brief, and are to be made daily. The newly-formed cicatrix seems to soften under this treatment; muscular rigidity rapidly disappears; periostoses following injuries of bone are rapidly reduced in size. The matter appears to deserve a further trial.

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[1] Mitchell, op. cit., p. 245.

[2] Berliner klin. Wochenschrift, 8, 1871.

Electrolysis is supposed to explain the cure, since the current is applied without interruptions; and electrolysis, even by the cutaneous method, has an unquestionable influence upon the tissues.

Paralyses supervening upon diphtheria and the acute eruptive fevers, including cerebro-spinal meningitis, require no special mention; they are apt to have the characteristics of peripheral lesion, and are in general very fit subjects for electric treatment.

Neuritis. "This expression has with us only a symptomatic signification," says Benedikt. It is employed to denote the condition of a nerve, in which the latter is painful when galvanism is applied, and there is anæsthesia or hyperæsthesia, with tinglings, palsy, spasm, etc., in the region supplied by the nerve. These conditions, if due to the state of the trunk of the nerve, or the plexus, are very often relieved by galvanization.

Of special localized paralyses the following may be mentioned:

Paralysis of the muscles of the orbit is a promising object of treatment, if the case is recent; *i. e.*, not more than a month or two old. *Mild* faradic currents are to be applied by a small electrode placed upon the closed eyelid, as nearly as may be over the paralyzed muscle. Direct application of this current to the eyeball is extremely painful, and is therefore to be avoided; Mr. Brudenell Carter, however, employs it for the relief of strabismus, making applications to the weakened or paralyzed muscle after section of its antagonist. The interrupted current (galvanic) from two or three cells may also be used by direct application. The sphincter iridis muscle reacts, producing contraction of the pupil, when the current is applied at two points to the sclerotica near

the corneal insertion of the iris. Galvanization of the cervical sympathetic is an authorized treatment in various paralytic affections of the eye, including mydriasis, myosis, and ptosis.

In recent peripheral palsy of the facial nerve the prognosis is very favorable when the reactions under galvanization and faradization remain normal for the first two or three weeks; the more the reactions are weakened, the longer is the paralysis likely to last. If, as is more common, faradic reaction alone is impaired or lost, we may usually expect a complete cure in one or two months; but if the galvanic reaction is also quite lost, the cure will take a year or more, and may very likely be imperfect. If the case has lasted longer than three months when brought for treatment, the prospect of entire cure is small. The galvanic current is generally preferable; sometimes alternate galvanization and faradization is of use.

Facial paralysis of central origin is not intended in the above remarks. It may be treated in accordance with the rules already given for cerebral palsies.

An apparatus for supporting the paralyzed side of the mouth has been invented by Dr. Detmold,[1] which may be of value in assisting the cure. A smooth plate of platinum is bent into a hook so as to support without hurting the mouth; a silver wire, soldered to the plate, runs across the cheek and hooks behind the ear, where it is soldered to a plate of zinc. The zinc, covered with moistened velvet, is laid flat upon the skin behind the ear. Thus is formed a small galvanic battery, acting upon the paralyzed muscles; besides which (and proba-

[1] New York Medical Journal, May and July, 1873.

bly more important) an artificial support is given to the feeble muscles, enabling them to retain their position, and hastening their recovery. Instead of this support, strips of plaster may be used.

In palsy of the intrinsic muscles of the larynx, some authorities prefer to apply the current directly to the individual muscles by means of Mackenzie's long electrode, used in connection with the laryngoscope, while others content themselves with applying the electrodes upon the outer surface of the larynx in such a way as to send the current through the paralyzed muscles. The presumption, however, is here in favor of the more delicate and accurate form of treatment by Mackenzie's method.

Paralysis of the diaphragm, a rare complaint, is treated by faradizing the phrenic nerves in the neck.

Paralyses of the genito-urinary organs are treated of in Section C.

To the group of peripheral nerve-paralyses may be subjoined the primary myopathies, Progressive Atrophy of Muscles, Pseudo-hypertrophic Paralysis, Metallic Palsy.

Progressive muscular atrophy presents a somewhat encouraging prospect. A patient and long-continued galvanic treatment of the sympathetic system, the spinal cord, and the nerves and muscles, is requisite, and occasionally arrests the disorder.

Pseudo-hypertrophic paralysis (Duchenne) is not likely to be much benefited by any treatment, but the author who names it has obtained a cure in the first stage of the disease, by faradization combined with *massage* and hydro-therapeutics.

Lead palsy is curable, or susceptible of relief, in most cases. Duchenne advises the use of powerful faradic

currents with extremely rapid intermissions, both in this and in the last-mentioned complaint. This treatment may exercise a curative influence, even though it cause no visible muscular contractions during the early applications. Galvanism is probably of greater value on the whole.

C. Pain, Anæsthesia, Functional Paralysis, Debility.

It is a general function of the electric force, when properly applied, to relieve pain and take away the sense of fatigue. And the fact that electricity is also a powerful stimulant of the nutritive processes cannot fail to remind us of the theory of Anstie, connecting neuralgia with imperfect nutrition. Anstie[1] has used the strongest terms in recommending the galvanic current in the treatment of the latter disease. He applies the current more frequently than is commonly recommended. In general, faradism is of much less value; although extremely important when points of local tenderness or anæsthesia exist, which may be treated by the anode of a galvanic current or gentle stimulation with a wire-brush. Galvanic currents are certainly of leading importance in neuralgia; but advantage is often derived from cutaneous faradism, as recommended by Duchenne. It is proper to attend to Benedikt's suggestion in regard to treating the *locus morbi;* if we fail with applications to the nerve, we must treat the plexus or roots, or the spinal cord or brain, or the sympathetic system, of which more by and by.

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[1] Neuralgia and the Diseases that Resemble It, p. 199, et seq.

Tic douloureux claims the galvanic treatment, and the physician may expect some success; authorities are not so agreed upon this, as in the case of pure neuralgia. Galvanism will *sometimes* cure, with almost miraculous rapidity, an apparently inveterate case, and its absolute failures are rare.

Rheumatism of the scalp and other muscular tissues is greatly soothed by faradic currents. A quantity of this form of electricity, so slight as to be imperceptible to the conducting hand, is capable of relieving many cases of aching steady pain of the brow—a peculiarly sensitive spot. In true myalgia great and immediate relief is almost certainly attainable by the use of the faradic current, directed so as to rouse the muscles to contraction; this process, in my own experience, is usually painless. True rheumatic pains of the muscles are sometimes relieved with great rapidity by galvanism; it would be well in such cases to include the spinal cord and the plexus in the circuit, and use a "stabile" current.

Headache in various forms is often relieved by one or the other of the currents. As to the mode of administration, rheumatism of the scalp suggests local faradization by the "electric hand;" confusion of thought, inability to apply the mind, are indications for the use of direct cerebral galvanization; and when the disease is a well-marked hemicrania, it is also a proper subject for galvanic treatment. Good authorities have found this of use in hemicrania, others have not succeeded with it; a want of agreement exists upon this point, perhaps referable to the difference in the methods employed.

The range of application of both classes of currents in relieving pain is very great; we will here simply men-

tion as excellent subjects for treatment, neuralgias of the viscera, including dysmenorrhœa, gastralgia, and lead colic; the pains of rheumatism, whether muscular or articular, and of rheumatic gout, cancer, etc.

Insomnia and mental anxiety, due to overexertion of the brain, are advantageously treated by galvanism; yet it is necessary to proceed with caution, and not to infer that if three applications have done good, therefore a fourth can do no harm. A galvanic current passed through the spinal cord refreshes some persons like a stimulating bath, while others are neither benefited nor injured by the application; in still another class, the ordinary currents are not borne at all, and the doses must be very greatly reduced or the application suspended altogether. General electrization, described elsewhere, is often useful in the condition here mentioned, and in its frequent concomitant, dyspepsia. A patient is often soothed and made sleepy by the application of electricity, and some people speak of being drowsy on the following day.

Cerebral and spinal congestion or anæmia are mentioned by several authors as proper objects of electrical treatment. By none is the latter so highly praised as by Hammond, whose original researches upon this point give weight to his opinion. He galvanizes the cervical sympathetic for cerebral congestion. In spinal congestion the current is directed down the spine; in spinal anæmia, upwards.

"Spinal irritation," with tenderness of one or more vertebræ, and various other symptoms of pain, debility, and "nervousness," is often susceptible (not always) of great benefit from galvanism; the tender point or points should be especially treated by direct applications, the

current being made as weak as may be necessary. The reader is referred to the observations of Neftel, in the "Archives of Scientific and Practical Medicine," for some further remarks and illustrations of the power of electricity over "backache," dysmenorrhœa, etc.

Opium-eating and alcoholism, as dependent on a want of tone of mind (doubtless with a physical base), and certain other conditions, which may be premonitory of insanity, are susceptible of relief through the use of the galvanic current; Althaus supports this statement by three cases.[1]

Catalepsy has been treated by good observers with a galvanic current, applied to the spine, which sometimes seems to relax the muscles; there can be no objection to the treatment.

In hysterical paralysis, electricity may be found of the greatest value. The experienced physician will not let electricity, or anything else in the way of treatment, interfere with "moral influence." It is for him to judge whether a given case is to be cured by his simple "Rise up and walk!"—or whether the malady has affected the system so far that appeals to the patient's will and intelligence are inadequate to accomplish a cure. That the latter is sometimes the case admits of no doubt. The diminution of electric reaction in the muscles, observed in prolonged cases, is an evidence of the fact. If electricity is employed, the galvanic current is applied to the spine, and nerves, and muscles; faradism to the muscles. Cutaneous anæsthesia ought to be treated with the electric brush; this application will sometimes cure both anæsthesia and paralysis very quickly. Hysterical

[1] Treatise on Med Electricity, 3d ed., p. 498; compare Onimus and Legros, op. cit., p. 501.

aphonia is treated by vigorous shocks of a faradic coil, applied to the outside of the larynx; or in obstinate cases to the interior, by means of a Mackenzie's laryngeal excitor. The Leyden jar is probably not superior to the faradic coil for this purpose. Galvanism appears to act favorably upon the general tone of the nervous system; and further, although we cannot assume that it possesses any specific antagonism to "hysteria," it certainly helps to conquer the tendency to spasmodic action.

Dyspepsia and general debility have been largely treated by Beard and Rockwell, with their methods of general faradization and galvanization. The value of their results is unquestionable; though the method is somewhat tedious, and other modes of application may therefore be tried.

Constipation, when chronic, is curable by electricity; perhaps always so, if the patient has sufficient perseverance. Acute constipation, with alarming symptoms, has repeatedly been relieved by electricity. Strangulation of the intestine has been cured by Duchenne in one instance with the faradic current; in two cases he failed; a number of other cures are reported by various observers.

Paralysis of the bladder is frequently relieved or cured; applications may be made in the greatest variety of ways, within the bladder, or bladder and rectum, or upon the walls of the abdomen and the loins. Care must be taken not to *burn* the mucous membranes with galvanic currents! Galvanization is useful in spasm of the bladder, and in incontinence and enuresis.

For prolapse of the rectum the sphincter may advantageously be faradized. Spermatorrhœa and nocturnal emissions are greatly benefited; impotence, when due to

the disturbance exercised by these latter complaints, and similar essentially transitory conditions, is often curable. There is an incurable form, characterized by coldness and anæsthesia of the member, and total loss of sexual appetite; but if curable at all, the result will probably be attained by some one of the various methods of electrical treatment, comprising applications to the spine and the parts about the genitals, to the latter directly, and to the urethra at the opening of the ductus ejaculatorii.

D. Spasm.

Spasmodic disorders are as a class so distressing, and so difficult to treat, that anything which offers a tolerable chance of relief may properly be tried. Electricity, in the form of the galvanic current, presents such a chance.

The "tic convulsif" of the facial nerve ought to be treated with electricity, since cure is not impossible, and some relief may probably be obtained. The positive pole is placed upon the part affected, and the negative upon some indifferent spot, and the current is to be stabile, or labile, or both.

Hiccup, when it becomes a disease, may be relieved by faradizing or galvanizing the phrenic nerve, or faradizing the skin of some distant portion of the body; and yawning, if it becomes distressing, may be treated by cutaneous faradization or spinal galvanization.

Torticollis may be due to a palsy of a muscle or muscles on one side of the neck, and is then to be relieved by curing the palsy; but if the affection is spasmodic, the prognosis is not favorable; treatment consists in

stabile galvanization of the contracted muscle, and faradization of the antagonist, which may procure temporary alleviation, perhaps a cure, if carefully followed up. Fisher[1] has successfully combined myotomy with faradization, and systematic exercise of the muscles of the neck, in chronic spasmodic torticollis. Clonic spasms of muscles of the neck or trunk, assuming a rhythmic form, are most unpromising cases.

It is possible that new methods of administering electricity may be devised, which will fill the gap we have pointed out. And yet a candid observer cannot but admit that our knowledge of causes is here at fault, quite as much as our skill in remedies. At any rate, it is worth while to consider whether the English are not right in ascribing importance to the "franklinic" or static electrization, in the treatment of spasms, tremor, and neuralgia. As an instance, I would refer to Dr. Tibbits's case[2] of facial spasm, of thirteen years' duration, which was cured by "electrization by sparks along the lines of the nerves distributed to the affected muscles." Dr. Radcliffe's method of charging the patient with positive electricity from the friction-machine or the *galvanic battery*, and allowing him to remain, so charged, upon the insulating chair for twenty or thirty minutes, is worthy of a trial; it cannot be said to have established itself as yet.

Writer's cramp has been treated with remarkable success by Dr. Poore, of Charing Cross Hospital.[3] This author believes that he sees an analogy between this disease and stammering, and has therefore employed the

[1] London Med. Record, December 1, 1873.

[2] Handbook of Medical Electricity, p. 104.

[3] "Practitioner," September, 1872, August, 1873.

treatment found so useful in the latter affection, namely, regular systematic drill of the muscles. This being impossible to the unaided will of the patient, a galvanic current was passed through the belly of each muscle in turn; and, while in the state of relaxation, each one was exercised in light gymnastics. In some cases, different points of application are chosen; for instance, positive pole in the axilla, negative on the ulnar nerve at the elbow; with exercise of the interossei; or, positive over median nerve in the upper arm, negative over flexor longus pollicis, etc.; or, positive higher up in the axilla, and negative over the musculo-spiral as it bends forward alongside of the supinator longus above the elbow. The strength of the current, in these applications to the nerve, should be sufficient to cause simply a slight tingling, but not contraction, when the current is made or broken. Quite recently, the method has been successfully applied by its author to clonic torticollis.

Apropos of this treatment of Poore's, which seems very well calculated to attain its object, a number of considerations suggest themselves. It will be observed that the current is passed in the downward direction. Is it likely that the reverse procedure would have proved inefficacious, or would have aggravated the disease? One is, for a moment, at a loss what to reply. Authorities cannot be reconciled. It is worth while, however, to pay attention to the position of the poles of the battery. If any physiological datum could be suitably applied in electro-therapeutics, the well-established depressant action of the positive pole would seem to be such a datum; and in these cases of Poore's we find the positive placed upon the upper part, the more susceptible part, of the nerve, which appears a rational way

of influeneing an overexeitable organ. It should not be forgotten that a *sudden* application or removal of the current would frustrate the intended sedative action.

If peripheral galvanization fails, it will be proper to galvanize the eord, or the brain. The direction to be given to the current in "spinal galvanization" is not a settled point; and as the proeedure is very often employed, both in spasmodic and other diseases, we will take the opportunity for making some general remarks upon this matter. Benedikt (in speaking of locomotor ataxia) says that when the disease is situated high up in the spinal eord, the ascending current should be used; when in the lower portion, the descending eurrent. This rule is perhaps justified by the consideration, that the negative pole aets more powerfully than the positive. But Onimus bids us always use an aseending eurrent, in treating this disease, and he forbids us to apply galvanism to the limbs, while Benedikt employs it in all cases where it is not eontraindicated by the existence of neuralgia. Hammond[1] tells us that the applieation of an ascending current irritates the sympathetic; that the same current, in the ease of spinal irritation (anæmia), "seemingly conduces to the dilatation of the bloodvessels;" while in spinal eongestion a downward current "probably lessens the calibre of the vessels, and is eertainly benefieial, while the upward inereases the intensity of the symptoms." But Onimus and Legros[2] tell us that the aseending current augments the excitability of the cord, and exaggerates the reflex actions, while a descending eurrent cheeks them. They say further:[3] "We know that the ascending cur-

[1] Dis. of the Nervous System, pp. 423, 426, 394.
[2] Op cit., p 288. [3] Ibid , p. 220.

rent closes the bloodvessels, while the descending current increases the afflux of blood."

Such being the theoretical difference of opinion, it remains for us to ascertain for ourselves by trial in each case, whether either the upward or the downward direction has an actual injurious influence in increasing irritability. Probably the matter is of subordinate importance; the real points to be kept in mind being that the interrupted and the labile currents are stimulants, the voltaic alternations violent stimulants, the action of the negative pole is the preponderant one, and the action of a perfectly uniform current is probably a sedative in some ways, particularly at the spot where the positive pole is applied. Generalization cannot be carried much further with safety.

As to the faradic current, it may be employed by direct application for the purpose of relaxing muscular spasm, as in torticollis, the force of the application, at first mild, being gradually increased to a point beyond what could possibly be borne at first. It will sometimes produce relief, and it is very curious to feel the muscle sinking away from under the point of the electrode; but I doubt whether this or any other method can be relied on with entire confidence in spasmodic diseases; we may nevertheless try the several methods with considerable hope of relief. Other local spasms, such as that of the muscles innervated by the spinal accessory, have also been successfully treated by electricity.

The "electric bath," which is essentially a form of general faradization, is recommended by Chapot-Duvert[1]

[1] Bull. de Thérapie, lxxx, p. 385.

for the relief of mercurial and alcoholic tremors. Galvanism is a proper treatment.

In stammering, we have to consider whether respiration is properly performed; if not, the phrenic nerve may require stimulation. Vocal gymnastics may be essentially assisted by galvanic currents passed through the larynx from side to side at each lesson.

In estimating the probability of a cure of paralysis agitans, the age of the patient is to be considered. In old age scarcely a hope can be entertained; in youth the case is quite different, and galvanic treatment is indicated.

Athetosis, the extremely rare disease described in Hammond's work on Nervous Diseases, has not been benefited by electricity, as far as my knowledge extends.

Chorea is sometimes benefited by a galvanic current passed directly through the affected region. There is the same curious disagreement of authorities, already noted, as to whether the current ought to be passed *up* or *down*. This does not alter the fact, that galvanism appears to lessen the spasm. Ordinarily the use of arsenic, zinc, chloral, etc., is quite sufficient without electricity, in the case of children.

Tetanus and hydrophobia have been treated by a strong galvanic current applied to the spine, with temporary relief.

Epilepsy has been treated in the same manner, but it cannot be said that electricity is acknowledged as a regular part of the treatment. Hammond, however, has tried it extensively, and thinks the results quite favorable.

E. Neuroses of the Sympathetic.

Eulenburg[1] considers that hemicrania, angina pectoris, progressive muscular atrophy, Graves's disease, Addison's disease, and diabetes mellitus, are more or less palpably neuroses of the sympathetic system. He places a high value upon the galvanic current in the treatment of these diseases. Chvostek,[2] an excellent observer, has made a special study of Graves's disease, and appears to have achieved remarkable success in its treatment. Galvanism ought in these cases to be applied to the cervical sympathetic and to the spinal cord. The method of application to the neck has been described.

Benedikt galvanizes the cervical sympathetic for vertigo, neuro-retinitis sympathetica, progressive muscular atrophy, arthritis, lead-palsy, lead-neuralgia, neuralgia in general, tabes dorsalis, and a great many other complaints; in which he is imitated by many physicians.

"Galvanization of the cervical sympathetic" is, in fact, a routine practice with many. Adopted from theoretical considerations, it is found to have been so often followed by amendment of the disorder, that it has retained its place among the list of "practical measures," while the original theoretical grounds for its employment have had to be modified. And chief among the reasons for this change of view has been the fact—palpable, though at first neglected—that the current cannot possibly be confined to the cervical sympathetic, but must of necessity, when applied in the prescribed mode, affect the vagus, the depressor, the phrenic, and various

[1] Berliner klin. Wochenschrift, 15, 1873.

[2] Wiener med. Presse, 1871, 1872.

branches of the cervical plexus, if not that plexus itself; to say nothing of the cervical portion of the spinal cord (which is expressly included in one of the rules of treatment), and the ganglia of the base of the brain. But Benedikt himself has at last come to admit what is here said; in his own words, "expressions like *galvanization of the sympathetic*, and *spinal-cord-nerve* current, have for him only a technical signification, and are the expressions of a method of applying the rheophores." Still, there remains much looseness of thought and speech in this matter. To take one example of many, a recent author has published cases of severe infra-orbital pain, cured by what he calls "galvanization of the cervical sympathetic;" the method, however, actually consisted in placing the negative pole upon the nerve in question, and the positive upon the seat of pain!

Cyon reminds us of the fact, demonstrated by Claude Bernard, that the vaso-motor nerves of the upper extremities arise from the roots of the *dorsal* spinal nerves, from the third to the seventh pair; and those for the lower extremities from the lower dorsal and the lumbar roots. He suggests that the axilla and the sciatic notch are also excellent places for reaching these nerves. Applications designed to affect the vaso-motor nerves should, according to him, be rather prolonged, viz.: from ten to twenty minutes in duration.[1] All these suggestions are most valuable, and constitute, apparently, a more rational scheme of treatment than that of cervical galvanization, which has hitherto been so generally used.

We have had occasion already to speak of one or two of the diseases above mentioned. For the rest, diabetes

[1] Op. cit., pages 207, 213.

mellitus appears most deserving of the galvanic treatment. Claude Bernard[1] considers it as a nervous malady due to an excessive action of the "nerf désassimilateur du foie," which causes the premature decomposition of a material which should subserve nutrition in some other manner; he believes that "if the sympathetic could be galvanized" it would probably be a useful proceedure. Bischoff[2] reports a case, due to chronic disease of the floor of the fourth ventricle, which was treated for thirty-two days by galvanization of the neck and of the liver; at the end of that period the quantity of urine had fallen from 2885 to 2056 grammes, and that of the sugar from 24.6 to 11.69 grammes.

"Besides these established forms of disease" (says Eulenburg), "we come by experience to recognize a great many sporadic cases, which cannot be brought under any general title, but which, under a great variety of form, present one symptom or groups of symptoms which may, with partial or entire justification, be considered as due to functional disturbances of the sympathetic nervous system. Account must be taken of the difficulty of stating whether the cerebro-spinal system or the sympathetic is at fault. It may be quite impossible to say whether a given case of accelerated pulse is due to stimulation of the accelerator fibres, or to paralysis of the vagus-regulator fibres. In mydriasis it may be doubtful whether the cause is due to irritation of the dilatator pupillæ, or to paralysis of the sphincter iridis (motor oculi)."

Without discussing the question of the "trophic

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[1] Leçons de pathol. expérimentale, 1872.

[2] Quoted in Brit. Med. Jour., October 11, 1873.

nerves," we will simply enumerate a group of symptoms relating to nutrition and circulation, which are more or less distinctly connected with the sympathetic system, and which may be classed together, as frequently relieved by the galvanic current:

Ptosis, unilateral sweating, or absence of perspiration; difference in the temperature of the two sides of the body; mydriasis and myosis; local lividity or pallor; atrophy of skin, nails, and cellular tissue; hypertrophy of skin; local muscular paralysis; local hyperæmia or anæmia. This list is not intended to be complete, but only suggestive.

A few remaining morbid conditions may be conveniently spoken of in this place before going on to midwifery and surgery.

Rheumatic gout has been treated by Althaus[1] with most encouraging results. He obtains relief from pain, from sleeplessness, from dyspeptic symptoms, and a decrease in the size of the swelling of the joint. Pain is usually relieved by a very few applications, but deformities require a treatment of many weeks or months, though they are pretty sure to yield at last. Both local galvanization and treatment of the cervical sympathetic are employed; the pit of the stomach and the cervical spine are other points for application. The method, in short, is a good deal like Beard and Rockwell's central electrization. My own experience decidedly confirms that of Althaus.

Rheumatism, in a great many forms, is much benefited by electricity. The acute febrile affection is not adapted

[1] British Med. Journal, September 28, 1872.

for the treatment, but apart from this, scarcely any case can be brought forward which would not be likely to derive benefit, and frequently much more benefit than any other treatment could confer. Both currents are employed, and it is not easy to specify when one should be preferred to the other.

Retention of bile in the gall-bladder, due to catarrhal swelling of the duct, has lately been treated by C. Gerhardt in Würzburg[1] by faradization of the gall-bladder, repeated several times, a few seconds at a time.

Enlargment of the spleen, as a sequela of intermittent fever, has been successfully treated by Duchek;[2] his method consists in dry faradization of the skin over the region of the spleen.

Spasmodic asthma is treated by Neftel with the galvanic current; applications are made to the pneumogastric.

Skin Diseases. Beard and Rockwell[3] say that herpes, prurigo, and eczema yield rapidly to central galvanization; psoriasis and pityriasis are quite slow and obstinate. The subject is interesting, and ought to have full trial.

Artificial respiration can readily be procured with a faradic apparatus in the following manner: The positive pole is placed upon the epigastrium. The negative, armed with a good-sized sponge if convenient, is placed at the outer border of the sterno-mastoid muscle, not quite half way up, in front of the scalenus; it should be pressed firmly in against the outer edge of the sterno-mastoid. This being done, the current should be intro-

[1] Berliner klin. Wochenschrift, 27, 1873.

[2] Wiener med. Presse, 1870.

[3] Medical Record, August 15, 1873.

duced, tolerably strong, and should be increased in strength until the diaphragm contracts. When this has occurred do not remove the electrode, but interrupt the current in some other way; and at the proper intervals renew and interrupt as before, so as to imitate the rhythm of breathing.

This method is given by Ziemssen, and was employed by him to good purpose in saving the lives of persons asphyxiated with carbonic oxide.

Duchenne prefers to apply electricity by inserting one pole into the mouth and the other into the anus. He considers both currents of equal value for this purpose. Great precaution must be taken to avoid an excessive current. If the galvanic is used, we should begin with a few cells and gradually increase the number; if the faradic, we may dampen or diminish the initial intensity by some such means as the water rheostat, and we should in any case stop short of that degree of intensity at which the muscles of the limbs are seen to contract. Onimus and Legros caution us, if using galvanism, not to withdraw the current until respiration and pulsation are completely established. The current (galvanic) should be continuous, and may be quite strong.

But in inexperienced hands, the safest procedure is that of cutaneous faradization of the præcordial region, by placing one pole on the left nipple, and with the other stroking the skin (which must be well dried) over the apex of the heart. The current may be feeble or intense. This method is extremely valuable in syncope, and has its use in other affections, as angina pectoris.

It is scarcely needful to add that the administration of chloroform should not be practised, unless the operator has at hand an induction apparatus in good running

order; the moment for saving life should not be lost in running for a battery, for probably no other remedy is of equal value, provided the application is made instantly upon the appearance of syncope. Vigorous cutaneous faradization of the region of the heart will sometimes stimulate the latter to action. Some authorities insert the two poles of the battery into the mouth and rectum, and apply a current as powerful as may be borne. But direct faradization of the phrenic in the neck, as above described, is not at all difficult to effect, and is perhaps preferable.

In resuscitating drowned persons, or asphyxiated newborn infants, electricity is very valuable. Other applications might be mentioned, but these are sufficient. We will add, however, that Fayrer, in his great work on the "Thanatophidia of India," recommends the application of heat and of electro-magnetic currents over the heart and diaphragm as valuable aids in combating the deadly prostration which follows the bite of poisonous serpents.

If the method just described is not adequate to rouse the patient, cardio-puncture may be employed. The following very practical directions are extracted from a report on electro-therapeutics, given in the British Medical Journal for December 13th, 1873.

"In puncturing the heart we must take care to hit the apex of the organ, which bears injuries very well; and this may be accomplished by introducing a needle into the middle of the fifth left intercostal space, about one and a half inches from the left edge of the sternum. By acting in this way the left pleura, the coronary arteries, and the internal mammary are avoided. The puncture should be made perpendicularly, and should be one and a half inches deep; in fat persons rather deeper than

that. All unnecessary manipulations of the needle, more especially in taking hold of it when the heart's action re-commences, should be avoided carefully. The needle is connected with the positive pole of a faradic apparatus, and a moistened sponge-conductor connected with the negative pole is placed over the pit of the stomach, or over the left seventh intercostal space. The current should be weak, and only act for a second at a time, then be interrupted and used again in a similar manner."

F. Obstetrics and Gynæcology.

Electricity has been found useful in promoting the flow of milk, restoring the menses, relieving malpositions of the womb, promoting the normal development of the womb when retarded, and assisting the pains of child-bed. The operation of galvanic cautery is of peculiar advantage in some cases of uterine disease, and will be described under Surgery.

The galvanic pessary of Simpson is made in the form usually employed as a support for the uterus; but it is composed of two metals, zinc and copper, and therefore furnishes a galvanic current when placed in contact with the animal fluids and secretions. The existence of the current is demonstrated by the deposition of zinc-salts upon that metal. Simpson believed "that the uterus developed itself around such a foreign body, when it filled its cavity, as it did around a fibrous tumor or ovary;" that is, the presence of the stem-pessary causes the same process of hypertrophy to be set up which is observed in pregnancy or fibroma uteri. He found great advantage from its use in the treatment of imperfect

development of the uterus, whether congenital in nature or due to superinvolution after pregnancy. In amenorrhœa he says that its action, slow and long-continued, will excite the action of the uterus with far more certainty than the repeated application of a stronger current; and he extends this favorable statement to very obstinate cases. He never saw the use of the instrument for the cure of amenorrhœa attended with any untoward results, although he and his assistants applied it in a very great number of cases. It is often proper to keep the instrument in place for months or years; and it rests with the judgment of the physician to withdraw it if required by symptoms of irritation. Frequent cleansing is desirable. From time to time the size of the pessary may have to be increased, as the uterus grows larger.

Byford[1] speaks very favorably of the instrument. In case the amenorrhœa is not due to deficiency in the size of the organ, he recommends that the pessary should be introduced for a week preceding the period of menstruation, and after the period is passed removed until the next month. Thomas employs the same instrument for amenorrhœa.

For promoting the development of the uterus, galvanic currents derived from the ordinary battery have scarcely been tried, but promise well.

As the broad ligaments of the uterus contain muscular fibre, it is a rational proceedure to faradize them in cases where they are relaxed, and the uterus has slipped down below its normal position. I cannot give an opinion as to the success of the treatment.

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[1] Medical and Surgical Treatment of Women, 2d ed., p. 82.

Fano has employed the faradic current in flexions of the uterus. He considers it capable of improving the contractility of the uterine fibres, and his method accordingly consists in the direct application of the current to that side of the womb where the fibres are stretched by the flexion; that is, to the convexity, the side *from* which the womb is tilted. One pole is placed here, and the other may be put in various places on the outside of the trunk, or thighs. It cannot be that the action is limited to that portion of tissue in contact with the electrode; rather, the nutrition of the entire uterus is more or less stimulated. Courty[1] considers that he has found this method of application a valuable adjuvant to his other treatment of the disease.

When the milk fails to appear after childbirth, the faradic current will often act very quickly. One or two applications, made directly to the breasts, may suffice. And faradism is well known as a powerful stimulus to the menstrual function, not only when locally applied, but in rare cases, when applied to the most distant organs, as the ear and the larynx. Probably in both cases the process is essentially a reflex one; the spinal centres receive an impression from the sensitive nerves, and reflect it upon the vaso-motor system. This explanation is at least consistent with one fact, viz., the *uncertainty* of the therapeutic action, whether galactagogue or emmenagogue. It is well known that the phenomena of reflex action may differ extremely in respect to intensity, even in healthy subjects; and not only so, but the vaso-motor system is subject to great individual differences of action in normal healthy life. With this extenuation, we are willing to admit that electricity will sometimes

[1] Traité pratique, p. 783.

fail entirely and unaccountably in curing the troubles we speak of.

Uterine Inertia.—In 1846, Simpson[1] published the results of eight experiments made with the faradic current upon women in labor. The application was made in the most effective manner, by placing one pole directly upon the os uteri, and the other upon the patient's belly, over the fundus. The observations were all made during the first stage of labor, in cases that were tedious and protracted. The results, as regards the frequency and the duration of the pains, were entirely negative.

Subsequently to these observations, however, the matter has been investigated with sufficient diligence to leave no doubt as to the efficacy of the faradic current in strengthening uterine contractions during the first stage of labor, and in renewing them if suspended. The reader is referred to the memoirs of Saint Germain[2] and Tachard,[3] of the Maternité of the Hôpital Cochin, for a series of observations confirming these views. Their method, like that of Barnes,[4] consisted in the application of the two poles to the skin of the belly, to the right and left of the navel. The current is allowed to pass from 20 to 40 minutes. (Tripier thinks 5 or 10 minutes long enough.) They claim that the pains are almost invariably strengthened, and increased in frequency; the form is not that of tonic contraction, as is the case when ergot is given, but intermissions occur like those of normal labor; thus, while the os uteri is rapidly enlarged, the child's life is not endangered by

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1 In vol. i of his collected works.

2 Nouveau Dict. de méd et chir. prat., t. xii.

3 De l'électricité appliquée à l'art des accouchements, 1871.

4 Lancet, 1853, vol. 2, p. 500.

continuous pressure. The placenta is very quickly expelled. It is noteworthy that Tachard insists on the propriety of giving ergot in every case, directly after delivery; he has observed very few cases of post-partum hemorrhage, and ascribes this immunity to the use of ergot.

Retention of the placenta, and hemorrhage after delivery or during a sluggish labor, are proper subjects for faradic treatment, but not to the exclusion of more ready measures.

It is popularly believed that electricity can produce abortion. Paul Dubois and Saint Germain did not succeed in producing labor-pains, when labor had not spontaneously commenced. Barnes was successful, but he ruptured the membranes first. The faradic current may be looked upon as a useful adjuvant, when such measures as rupture, or the introduction of a sound, do not act with the desired energy.

Extra-uterine fœtation has been successfully treated. Burci of Pisa punctured the tumor, and passed an electro-magnetic current through it. Allen[1] reports three cases, the diagnosis of one of which was confirmed by Drs. Agnew and G. Pepper; the application of the current from an ordinary electro-magnetic machine, through the vagina, directly upon the projecting parts of the tumor, appears to have arrested the growth in each case.

G. Surgery.

Under this head we shall speak of electrolysis, galvano-caustic operations, and some points besides.

[1] Trans. of Phila. Obstet Soc. in Amer. Jour. of Obstetrics, May, 1872.

Aneurism is an important, perhaps the most important object of electrolytic treatment. The methods employed by various surgeons differ somewhat, but the essential features of the operation consist in the introduction of needles into the sac, and allowing the current from a galvanic battery to pass until the surgeon judges that a sufficiently large clot has formed under the electrolytic influence of the current.

Coagulation, in the blood of living animals, takes place at both poles of the battery.

There are three products of the electrolysis of blood—a moderately firm, black, and dryish clot which surrounds the positive needle; a quantity of gas, which, in the shape of fine froth, surrounds the negative; and a fluid of the consistency and appearance of thin tar. The clot is, of course, valuable; so, also, is the froth, for it is tough and firm, and becomes more so as the gas disappears; but the tarry fluid is evidently a disadvantage.[1]

Holmes[2] classifies electro-puncture with manipulation, the introduction of foreign bodies into the sac, and coagulating injections, as justifying confident hopes that they may come to be used regularly in classes of aneurisms, in which they have already succeeded, though only occasionally, and as it were haphazard.

The operation is justifiable even in thoracic and abdominal aneurism. There is a necessity for further experience, before we can confidently state its merits. Surgeons are not yet agreed upon the details of the

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[1] John Duncan, M.D.; article in Edinburgh Med. Jour., Dec. 1872.

[2] T. Holmes; Lectures delivered before the Royal College of Surgeons, 1872.

methods to be used; as whether the positive or the negative pole, or both together or alternately, should be preferred; whether the needles should be coated (with shellac or rubber), to defend the superficial parts; whether the operation should be frequently repeated, or almost solitary; and how powerful, and how protracted, a single operation ought to be.[1]

The treatment of tumors by electrolysis promises to become an important branch of surgery. Decided success has attended this treatment in cases of polypus, nævus, varix, hæmorrhoids, condyloma, adenoma, neuroma, hydatid cysts; to which add hydrocele, urethral stricture, and various other surgical affections. In all of these, except stricture, the usual method consists in the insertion of needles, and the passage of a galvanic current. But the most important question under this head relates to the treatment of malignant tumors, which has lately been carried out, and fully explained[2] by Neftel, of New York.

It would be altogether premature to decide upon the merits of Neftel's methods. In a technical point of view his procedures are very correct, and are well adapted to bring the morbid tissue under the influence of the electric current; the question remains, whether that influence is likely to do more in a curative way than the ordinary operative procedures. In regard to this the following points may be stated:

First, Neftel assumes that there is something special in the action of the current, a power of selecting the

[1] Duncan and Fraser, l. c.

[2] Virchow's Archiv, vol. xlviii, p. 521.

heterologous new-formations in the neighborhood of the poles, in preference to the healthy tissues. He says he has observed under the microscope that cancer-cells yield sooner than healthy cells to the destructive action of a galvanic current. In this point he differs from others; for instance, the two Bruns, who consider that the destructive action of the current is strictly and wholly due to the action of the alkali developed at the negative, and the acid at the positive pole. The electrolytic treatment, considered thus, is simply a treatment by caustics.

Second, he does not claim that galvanism exercises a special influence upon the development of cancer in parts of the body remote from the points of application. No such claim can reasonably be made; but, on the other hand, he does not fail to remind us that the modern views of cancer (Virchow) ascribe to it a strictly local existence during its early stages, and it is during this period that he hopes to destroy the germs, while only a single organ is infected.

Third, it is said by him that the reaction is very slight; that fever is almost never present, even after severe operations. This appears to have been true in regard to his operations on cancer; but the case of electrolysis of a uterine fibroid (myoma) ended fatally, by peritonitis due to malposition of the needle.

Fourth, he admits the possibility that galvanism may in some cases act as a stimulant to the growth of portions of tissue which are not destroyed by it.

As regards the results of the six cases of scirrhus of the breast, reported in the article quoted, *two* had relapses and died, respectively ten and twelve months after the first operation, although a second and third operation had been performed in the interval. A third

case presented very grave symptoms of constitutional infection three years after the operation. The remaining three were living, and in good health, at fifteen months, eighteen months, and three years respectively, after the operation. In one of these last cases the tumor had been twice excised, and was pronounced by Marion Sims to be cancerous; the other two were also well-marked cases.

In three of the cases excision had been performed at least once; the case of Marion Sims is one of these; and of the other two it may be said that a second excision could not have prolonged life beyond the actual periods of ten and twelve months.

In fine, the chief advantages claimed for the operation are two: its comparative freedom from danger, and its assumed power to destroy cancer-germs in the neighborhood of the needles somewhat more effectually than is done by the usual expedient of *removing a zone of sound tissue* by the knife along with the tumor.

While it must be admitted that six cases are a small number to build statistics upon, yet it is true that the results, as far as they go, are more favorable than those usually obtained in treating cancer.

Neftel prefers to operate upon a tumor which is hard, of moderate size, and of slow growth, and which has not involved the entire mamma. The needles, from two to four in number, are to be inserted quickly, and afterwards connected with the negative pole of the battery; then the positive pole is attached to a broad moist plate, which is kept applied to various parts in the neighborhood of the tumor; then the current is gradually introduced, one cell at first, till thirty-five or forty-five cells are in circuit. The time varies from twenty to thirty min-

utes. Withdrawal is effected gradually. Chloroform may be given, especially if a severer form of application be used, which causes a large mass to slough out at once. After the primary operation, which may be repeated at brief intervals two or three times more, it is necessary to apply a mild, painless galvanic current every day to the diseased region for the space of a quarter or half an hour. This after-treatment is to be continued for some months, and is thought of great importance by Neftel.

It ought to be added, as a fact confirmed by many observers, that the pain of malignant tumors is greatly relieved by the insertion of needles and the passage of galvanic currents.

Naso-pharyngeal polypi have been treated of late with great success. Paul Bruns[1] gives an analysis of ten cases; one of which was not terminated, a second was cut short by death from typhoid fever, and the remaining eight were cured. A later report gives an additional, and very successful case, cured in eleven sessions; one of the others required one hundred and thirty sessions. The average strength of the current is about eight cells of Frommhold's battery. The real importance of the operation lies in its applicability to cases where the polyp is inaccessible to ordinary surgical treatment. Bruns believes the mode of action to consist in successive destruction of tissue; first, by gangrenous death of the parts lying close to the needle; second, by ulceration in the vicinity of those parts. It is very probable that there is also a "catalytic" or "dynamic" action.

[1] Berliner klin Wochenschrift, 27, 28, 1872; 32, 1873. Boston Med. and Surg. Journ., Nov. 28, 1872, and Nov. 1873.

Vascular tumors are treated by the needle operation, or by galvanic cautery. If small, they can generally be cured without a disfiguring scar, by the former operation. Varix and varicocele, and external piles, have frequently been cured by electrolysis. Small fibroid tumors, wens, and papillomata, are favorable subjects; lipomatous tumors are not favorable, owing perhaps to the poor conductivity of their tissue.

Enlargements of lymphatic glands have formed a frequent object of treatment by the electrolytic process, and the results are not bad. Thyroid enlargements, both old and recent, are also proper objects. Mackenzie speaks favorably of electrolysis of the latter, but I believe that he seldom uses it. Chvostek reports thirty cases; in one-fifth of which success was complete, in one-fifth no success was gained, and in three-fifths moderate success. The latter has treated indolent buboes in the groin with fair success.

In the eight cases[1] of hydatid tumors of the liver, reported by Dr. Fagge and Mr. Durham, slight febrile reaction occurred in every instance except one; it lasted about four days, and no suppuration occurred. In each case in which the patient could be examined, from three to six months after electrolysis, it was found that the tumor had very manifestly diminished in size, while in some instances no traces of the disease could be discovered. The galvanic current was employed by means of needles passed into the sac.

Other cysts may be treated similarly. Althaus and others have been very successful with hydrocele; the operation is without danger, and the disease seldom

[1] Medico-Chirurgical Transactions, 1871.

recurs. Rodolfi's method,[1] for which peculiar merit is claimed, consists in first evacuating the fluid, then touching the interior surface of the tunica vaginalis at every point successively, by the tip of a metal probe connected with the negative pole of two, three, or four Grenet's elements. It is nevertheless open to doubt, how far the cure is due to the effect of simple puncture, in these cases, and how much is owing to galvanic action.

The residua of old inflammations in various parts, such as fluid in the bursæ mucosæ, or the sheaths of tendons, or the tunica vaginalis, or the cavities of joints, can probably be absorbed more quickly when galvanic or faradic currents are passed through the parts; it is certain that pain is relieved. If necessary, the skin is punctured with needles, as electrodes, but treatment usually consists in the application of the poles to the moistened skin (cutaneous galvanization).

The value of galvanic currents in relieving granulations of the eyelids, and thickening of the cornea, has lately been praised by several observers; some apply the current directly to the spot, others to the outside of the lids, by metallic conductors. A similar beneficial result is believed by competent observers[2] to be attained in chronic catarrhal affections of the ear—"mucous deafness" and purulent discharges. The way to apply electricity to the ear has been described previously; but Campbell has a very good suggestion, to the effect that one pole of the battery may be applied by means of a sound to the pharyngeal opening of the Eustachian

[1] Quoted in the "Practitioner," Sept. 1873.

[2] H. Campbell, M.D.. "Deafness Treated by Electrolysis," etc. London, 1872. C. J. Blake, M.D . Archives of Scientific and Practical Medicine, No. 4, 1873.

tube, while the other pole is placed at the ear, in the meatus, which may conveniently be plugged with a wet sponge, to serve as electrode. He sometimes uses alkaline and saline injections of the tuba and middle ear, passing the electric current immediately after the injection is made; he thinks that the combination of these agents is more effective than either separately. Closure of the tuba Eustachii, and thickening of the tympanic membrane, or of the mucous membrane of the tympanic cavity, are thus often relieved.

But the benefits derived from electricity are not limited to the effects referable to electrolysis. Debility, or shocks of various kinds, the impression of great cold, or sudden noise, or extreme fatigue, or the exhaustion following acute fevers, are causes which are known to produce "nervous deafness," by which we mean a loss of hearing without discoverable disease of any organ. It is beyond a question that the galvanic current will sometimes *cure* such cases.

Paralysis of the tensor tympani muscle can be relieved by faradization, applying one electrode (by means of the wet sponge) to the membrana tympani.

The passage of the galvanic current momentarily increases the power of hearing in two ways; the limit of perception of musical tones is extended, and the intensity of perception is increased. This is true, not of the diseased ear only, but also in healthy organs. The current has also an influence upon tinnitus aurium, so frequent a concomitant of deafness; and the direction of the current (or the choice of the pole applied to the ear) is an important factor in this result, for when one pole diminishes tinnitus, the other frequently increases it. "As a rule, the current which diminishes the tinnitus aurium

increases the hearing, and the current which increases the tinnitus diminishes the hearing. In cases where the tinnitus is diminished without increase of the hearing, this effect is usually produced by the anode, the cathode increasing the tinnitus without a corresponding increase of hearing. When the hearing is increased together with an increase of the tinnitus, this result is usually obtained with the use of the cathode." (Blake, l. c.) These are circumstances which should govern our choice between the two poles. In case there is deafness along with tinnitus, select the pole which diminishes the deafness, even if the tinnitus be momentarily increased; for the latter may be expected to improve as the hearing grows better.

White atrophy of the optic disk, well marked, has been treated by several observers with galvanic currents. The most remarkable improvement was exhibited in Dr. Fraser's case,[1] in which the sight was so improved in a month's time, that the patient read $5\frac{1}{2}$ Snellen as easily as he previously read No. 20. Various methods, including applications to the cervical sympathetic, were used; there was *immediate* improvement after *each application*.

Bedsores and varicose ulcers are treated by Hammond[2] very successfully, by cutting a piece of silver plate as thin as paper to the size of the ulcer; it is laid upon the latter, a wire is led from it to a zinc plate of the same size, which is laid upon the healthy skin in the neighborhood, a piece of chamois leather wet with vinegar being spread between the skin and the zinc plate. Large sores are sometimes cured in this way in two or three days.

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[1] Glasgow Med. Jour., Feb. 1872. [2] Op. cit., p. 454.

A large number of cases of stricture of the male urethra have been treated by electrolysis. Mallez and Tripier have paid most attention to this matter, and report great success; the stricture is enlarged immediately by the operation, and the enlargement is claimed to be progressive. They insert a metal electrode, insulated except at the tip, as far as the seat of stricture; the negative pole is attached to this, and the positive pole, wetted, is applied to some neighboring part of the skin. A cylindrical slough is slowly formed around the metal in the stricture, owing to the development of free alkali around the metal; this slough is subsequently thrown off, and the cicatrix does not contract, but remains soft and pliable.

Vesical Calculus.—Prévost and Dumas, in 1823, attempted direct solution of a stone in the bladder by the galvanic current, a plan which was more fully developed by Dr. Bence Jones in 1852. The amount of instrumental manipulation, however, necessary to bring the wires into contact with the stone, and to maintain them there during the period necessary for its solution, is considerably greater than that required to crush the stone by the modern method of lithotrity, and must therefore be regarded at present as inapplicable.[1]

Electro-caustic Operations.—The power which the galvanic force possesses, of heating a conductor-wire, is well known, and has furnished in surgery a very important auxiliary.

Large batteries exposing several hundred square inches of metallic surface in a very few cells are required to develop the quantity of electricity necessary to raise wire to a red or white heat. The ordinary medical batteries

[1] Lecture by Sir Henry Thompson in the Lancet, April 5, 1873.

are entirely inapplicable to this purpose. The conductor-wires must be very large, and some sort of interrupter must be employed for restricting the flow of the current to the exact moments when heat is required. If this condition is fulfilled, the loop of platinum wire, or the caustic knife or button may be fixed in place with all necessary deliberation and care before any decisive step in the operation is taken. And with the aid of an apparatus for raising or lowering the metals in their bath, the quantity of the current—and therefore the intensity of the heat evolved—may be regulated from moment to moment. These circumstances give important advantages to the galvanic method of cauterization; but such advantages are neutralized by an ill-constructed or ill-tended apparatus.

I take the liberty, in speaking of this subject, to adopt the statements of Byrne, whose articles[1] upon the use of the galvanic cautery in uterine surgery are strongly recommended to the reader; they embrace a full and thoroughly practical account of the various methods and instruments, and a very careful history of eighteen of the seventy-two cases upon which the memoir is based.

Byrne claims that chronic catarrhal, inflammatory and ulcerated states of the intracervical mucous membrane yield readily, and in most instances to one application of the electric cautery, applied superficially. The same is said of inflamed and granular states of the urethral mucous membrane. There is generally no need of anæsthetics, but they are indispensable in urethral cases.

Besides these cases (of which his list contains 13),

[1] In the Amer. Journ. of Obstetrics, vol v, 3 and 4, vol. vi, 1, 1873; also in the Medical Record.

Byrne has treated by amputation, with the wire loop, the following:

Epithelioma, 19 (7 indurated or ulcerated only, and 12 of the vegetating or cauliflower character); encephaloid, 11; disease of the cervix (non-malignant), 5; fibrous and fibro-cellular polypi, 4; sessile fibrous tumors, 4; and a few others. Of the 30 malignant cases, 24 affected the uterus, either alone or with the vagina. The advantages claimed for this method of amputation are the following:

1. Security against hemorrhage. It is necessary, to this end, to avoid raising the wire to a white heat—to introduce the wire and knife *cold*—to cut gradually, and even to *pause* at intervals, too rapid operation being sure to leave open vessels—to avoid traction upon a tumor with the wire loop.

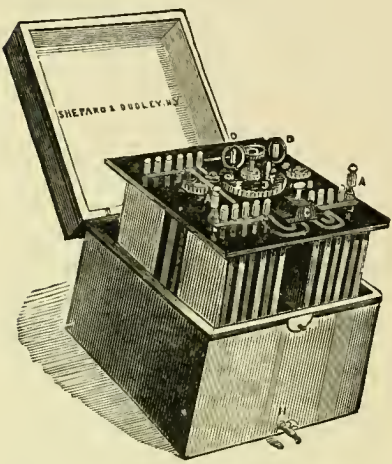
2. Immunity against peritonitis, cellulitis, pyæmia, and other sequelæ of intra-pelvic operations. It appears from a perusal of his cases that he is justified in his claim, that "in no single instance has life been jeopardized" by his operations. The fact that everything is occluded by the cautery—arteries, veins, and lymphatics—is of value in contributing to this favorable result.

3. Respite and relief are given in cases acknowledged to be of hopeless malignity, by removal of the parts most diseased. In cases of carcinoma, affecting primarily and extensively the *body* of the uterus, he considers that little advantage, if any, can be derived from the use of the electric cautery.

A healthy discharge of pus is observed as a rule about the fourth day after operating. A cicatrix does not seem to form; but the cut surface, when healed, looks as if

covered with mucous membrane. The operation is "the quickest, safest, most painless, and by far the most successful" treatment of the large class of cases requiring operative removal.

Fig. 17.



Battery for Electro-cautery used by Byrne.

As regards the battery, it is composed of carbon and zinc immersed in Grenet's solution (bichromate of potassa, sulphuric acid, and water), and should be capable of raising to a white heat from five to eight inches of No. 16 wire; no bellows is required; the metals are not immersed, except when in use. Other operators often prefer a constant battery like Grove's.

A variety of knives, scoops, and buttons for burning,

Fig. 18.

Galvano-caustic Knife.

are constructed; their uses are not confined to uterine surgery; but the larynx, pharynx, mouth, nostrils, and

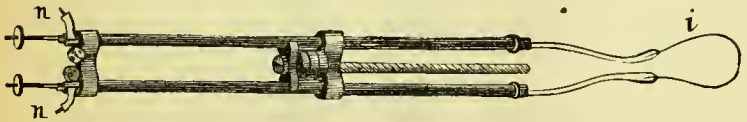
ear, furnish a wide field for their employment.[1] Considerable skill is, of course, required in managing the instrument; but there seems to be no reason why gal-

FIG. 19.

Galvanic Burner.

vanic cauterization should not be largely used, even in the larynx. As for the external auditory meatus, that

FIG. 20.



Galvanic Écraseur.

forms rather an exception; and it is very doubtful whether the galvanic cautery ought to be applied to the membrana tympani; the pain and reaction are too violent.

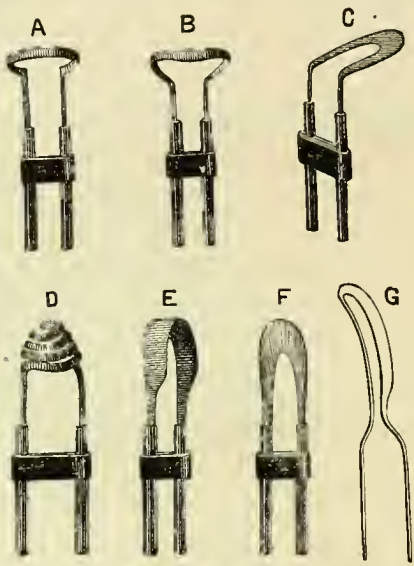
Tracheotomy may be performed by the galvanic knife; or by looping a wire through a portion of the whole thickness of the tissues, and making it cut its way out by traction. It may be so performed as to avoid hemorrhage; but at Tübingen, where it was first performed, it has been abandoned.

Lupus may be treated advantageously with the galvanic cautery; one application is said by Neumann to

[1] See Voltolini, "Die Anwendung der Galvanocaustik im Innern des Kehlkopfes," etc.

destroy as much as twenty applications of nitrate of silver; the former causes less pain, and the pain disappears

Fig. 21.



Galvanic Scoops and Burners.

very soon after the operation. A white heat gives less pain than a red heat, but the latter is generally preferable.

In respect to deformities, it may be briefly stated that club-foot is often benefited by improving the nutrition and function of the muscles. A few cases[1] appear to be purely functional, and can be cured without tenotomy. In lateral curvature, also, weakness of the spinal muscles is often an important element in the causation of the deformity, and the faradic current furnishes a very rational aid to the treatment.

[1] Duchenne, Gaz. Méd. de Paris, 1873, p. 326.

CHAPTER VII.

CAUTIONS.

In deciding upon the strength, duration, and frequency of applications, we have a number of very plain general rules to follow. And these rules may be reduced to one principle, namely, the avoidance of ill results; a statement which will seem less trivial when illustrated.

As regards the frequency with which we ought to apply a current of electricity, authorities are not wholly at one. In the cure of a paralyzed muscle, faradism may be employed daily, or even two or three times a day, taking care not to fatigue the muscle. We shall do well to consult analogy in this case. A good analogy is offered by the voluntary efforts of the gymnast, whose muscles are usually exercised every day at a stated hour; and if circumstances permit, and there is a strong motive for rapid development of the muscular system, it is not considered improper by "trainers" to exercise their man in different ways several times a day. But it ought to be carefully borne in mind that the systems of no two men are alike in point of endurance of fatigue. Muscular fatigue is only one kind, and is usually well borne by persons who are not much tasked in other directions. Mental fatigue, and that which comes from anxiety and responsibility, are quite as likely to

require our attention as the former kind, and fatigue from over-use of the stomach or the sexual apparatus are not unknown. Patients who show signs of deep exhaustion of nerve-force may bear the daily administration of a mild faradic current to the principal muscles of the trunk and limbs, in the manner called by Messrs. Beard and Rockwell "general faradization," but these authors take care to warn us against commencing treatment with a daily application. In fact, it is often necessary to let intervals of several days elapse between the sessions, and to make the applications very mild, and as brief as even five minutes. This remark applies to general faradization employed as a tonic to the whole system. As for the treatment of single paralyzed muscles or groups of muscles in persons otherwise healthy, there need usually be no hesitation in using faradism daily.

Similar observations will apply to the galvanic current. When its application is localized so as to exert comparatively little influence upon the great nervous centres, a daily use of the battery may be very desirable. Anstie[1] insists upon this point in treating neuralgias, and wishes the daily application to be continued for some little while after a cure seems to be obtained. Upon *a priori* grounds, one is inclined to believe that a malady which has such a strong tendency to return once in the twenty-four hours may properly be treated by a remedy applied with equal frequency; and it seems reasonable to assume that an organism whose round of function is completed within the period of a day and a night, and whose health is closely connected with the mainte-

[1] Neuralgia, and Diseases that Resemble It, p. 400 et seq

nance of regularity of habit, ought to derive most benefit from a regular daily use of electricity. A "sabbath" will also be found conducive to the best results; it may be observed once or twice a week. But analogies are treacherous.

The duration of a single application should be rather carefully restricted when one is using batteries of the usual strength. As a general rule three minutes is long enough for application to a nerve; from three to five minutes to the spinal cord; from one to three minutes to the organs of sight or hearing. When muscles are to be stimulated, the time allotted to each will, of course, vary; if, for example, a whole limb has to be worked upon, it is necessary to shorten the time for each muscle; but for a single large muscle, two minutes should be the utmost allowed, and for a group of muscles, five minutes should suffice. In general electrization a score or two of muscles have to be visited in turn, which may prolong the session (according to the exponents of the practice) to twenty or thirty minutes.

In using galvanic batteries of very little power, such as the "belts" and "disks" of Pulvermacher and others, it is probably safe—in most cases—to let the current pass for hours at a time. There is some danger that the skin may be injured by the chemical action of such batteries; and even when watched by careful nurses they will now and then make small burns, which are slow to heal, and easily spread if neglected. Besides this, the inconstancy of these apparatus is very great; another prime objection to their use.

Experiments have recently been made by MM. Le Fort and Groh with weak batteries composed of three

or four Daniell's elements, which have been allowed to act for days together upon local disease (myxo-sarcoma, osteo-sarcoma) and upon paralyses of various origin. The results are described as excellent, and one is inclined to attach considerable value, by anticipation, to this method, provided it can be carried out.

The strength of the current to be employed is a matter naturally in close relation with the duration of the application. A stronger current cannot be borne so long as a weaker. But there are limits of strength, beyond which we must not pass, limits which vary in each case, but which are defined by the occurrence of "accidents" which it is our duty to avoid. These undesirable results are the following:

1. Burns of the skin, or eczema, or persistent itching. One may, however, avoid these, in almost all cases, by increasing the size of the electrodes, and by shifting their position frequently when disagreeable sensations are complained of. These remarks refer only to the galvanic current, as the faradic causes no trouble beyond a temporary redness. A battery in which the chemical action is vigorous, as the favorite "bichromate of potassa" battery, is slightly objectionable upon this ground. There is considerable danger of burning the interior of mucous cavities, such as the bladder or rectum, if too strong currents are used, with a naked metal electrode.

2. Pain may be produced by excessive action of this sort. It is also sometimes due to incautious stimulation of muscles, but this ought to be avoided, as ought also the cutaneous pain which so frequently attends the passage of a faradic current. In stimulating a muscle, we should, if convenient, first moisten the skin, and keep the electrodes also moistened with salt water, in order

to give free passage for the current; the electrodes should also be firmly pressed upon the spot selected, if the muscle be not very superficial, since nothing is so painfully irritating as stroking the skin *lightly* with a *dry* conductor. This mode of giving pain is extremely valuable as a stimulus in anæsthesia, but must be shunned in other cases. Children, if not frightened, generally bear faradic stimulation of the muscles very well in judicious hands.

3. Violent impressions upon the retina and the auditory nerve ought to be avoided. In using galvanic currents about the head and face, this caution may be very important. Duchenne has recorded a case in which he himself destroyed a patient's sight by one application of the current from forty cells to the face. One ought especially to be cautious with a new battery, or one of an unfamiliar construction. But even with the Daniell cell, it is not always safe to begin with more than four or five elements; we may subsequently increase the power to eight or ten, if well borne by the patient, as is generally the case even in direct applications.

4. A group of other symptoms is sometimes produced by the sudden application of a galvanic current to the face, neck or head. A sudden cessation acts in the same way; so does the rapid increase or diminution of force. The symptoms in question are the following: Giddiness, faintness, nausea or vomiting, disturbance of the circulation or respiration, and drowsiness in all degrees, even to the point of prostration. The possibility of the occurrence of such accidents imposes great caution, and renders it desirable that the operator should be thoroughly familiar with the *technique* of his art. The sagittal direction, from the occiput to the forehead, is much safer in this

respect than the transverse, but even this rule is not sufficient to prevent trouble. I have seen a patient made very dizzy and "queer" by a *faradic* current, just strong enough to make the facial muscles contract, when one pole was placed on his neck and the other on the root of his nose.

5. Duchenne warns us against faradizing the pneumogastric in the œsophagus, as it may produce syncope; this will not happen if we convey the conducting knob to the *lower part* of the œsophagus.

6. Nausea, and a state of depression which may reach syncope, are produced by a galvanic current passed from the pit of the stomach to the middle portion of the spinal cord, while if the direction is reversed, no such results occur (Neftel).

7. Exhaustion of the system may occur after a single session, or after many. If transient, it may produce merely a deeper sleep than usual on the following night; in fact this effect is often desirable; and *vice versâ*, it would be well if patients could enjoy repose soon after the application is made. Without doubt they would derive more benefit from the treatment. But exhaustion which is not repaired before the next application is mischievous, and this kind of mischief may easily occur. A single limb may fail to recover from paralysis, for the sole reason that it is stimulated to the point of exhaustion by the electric treatment, applied longer than is borne.

8. It is but another phase of the same phenomenon that is presented when nervous excitability is visibly increased during a course of electric treatment, of which the object may have been the removal of excitability. It can hardly be necessary to explain the fact that one and the same therapeutic agent may occasion two sets of phenom-

ena directly contradictory of each other; how, for instance, bloodletting will sometimes relieve pain and convulsions, and at other times, when in excess, will bring them on. The fact that a powerful galvanic current, applied in a severe manner, may bring on an hysterical fit, does not at all invalidate the other fact, that a similar current will sometimes arrest violent local spasmodic action; it does, however, furnish additional warning against the excessive use of so potent an agent, more especially in the neighborhood of the great nervous centres.

9. An incorrect application of electricity is often capable of aggravating such pain as the patient already has, or even of establishing pain in parts previously free.

It not infrequently happens that a course of galvanic treatment has been continued for several weeks without much benefit; the physician then suspends the treatment for some weeks, and at the expiration of the period is gratified by seeing his patient return in a decidedly improved condition. The reader may speculate upon the cause. It is reported in good faith by competent observers, and may be paralleled by the fact which we have all had occasion to notice, that an invalid may return home from a foreign tour—from a sojourn at a German bath—with little visible improvement in health, but begins immediately to "pick up" as soon as he reaches home.

It may here be added that muscular contractions produced by the interrupted *galvanic* current are apt to be much more painful than those obtained by faradic currents.

The region of the neck in front of the trapezii is a dangerous one in several points of view. Not only is

it very sensitive to the galvanic current, but its muscles are, almost without exception, very easily influenced by mild faradic currents; they may respond with a painful jerk, not easily borne by one unaccustomed to this sort of mal-treatment. The physician ought to know how it feels in his own person before risking his patient's temper in this way.

The forehead is another place which tolerates only very mild currents.

The precautions to be observed in cases of cerebral palsy have been described in the previous chapter.

It should be borne in mind that the menstrual function is often stimulated, even by applications of electricity made to remote parts of the body.

CHAPTER VIII.

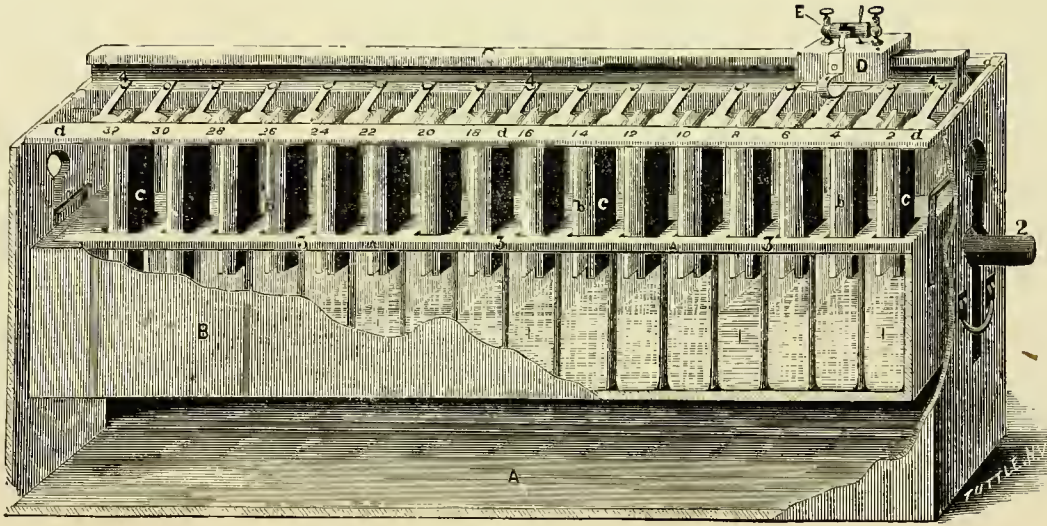
APPARATUS.

MUCH may be done with a very scanty apparatus; but a physician who really seeks to master the subject will not be content with either the faradic or the galvanic battery alone. A galvanic apparatus containing forty cells will suffice for most purposes; for treating the eye and ear twenty are quite enough. Hospitals and dispensaries should be provided with sixty cells; the Infirmary for the Paralyzed and Epileptic, in London, has one hundred.

Solidity of construction is a great desideratum, and seems well attained in the batteries furnished by Drescher, Kidder, the Galvano-Faradic Company, Curt W. Meyer, Hall, and other American manufacturers. Yet the workmanship of Hirschmann, of Berlin, and Stöhrer, of Dresden, has surpassed that of our own mechanicians. The most complete arrangement of apparatus is that of Brenner, containing, in addition to the ordinary apparatus, two arrangements for the automatic interruption of the galvanic current, besides a rheostat.

Whatever arrangement is adopted for increasing and diminishing the number of cells in use, it is of essential importance that *no break* should occur in the process. A battery should be tested by the galvanoscope; its poles being connected with the latter instrument, the current

FIG. 22.



Portable Galvanic Battery of the Galvano-Faradic Company. Above, commutator (E) and current-selector (D). Below, arrangement for raising and depressing the cells containing the fluid. It is a "Bichromate of Potassium" Battery, like Grenet's.

from one cell should be introduced, then that from two, three, and so on; this should be done gradually, while the needle of the galvanoscope is carefully watched to see if at any point in the ascending scale of strength the current is suddenly interrupted. A defect in the mechanism of the "switch-board" or "current-selector," as it is variously called, is a fault not to be excused. If we happened to be using, for example, the current from ten cells, and desired to increase the strength to eleven, it might occasion a most disagreeable shock to the patient if an unexpected break in the current should occur in the transit.

The *galvanoscope*, consisting of a compass-needle swinging in the centre of a fine coil of wire, is made of various degrees of delicacy. It furnishes a very convenient means of deciding, at any moment, whether the current we suppose we are using is actually present, and if so, in which direction it is flowing. It is not a fair test of the strength of a current, beyond the number of ten or twenty cells. A battery of my own, of 60 Remak cells, deflects the vertical needle as follows: 1 cell, 3°; 2 cells, 7°; 3–11°; 5–18°; 10–25°; 20–27°; 30–28°; 60–29°; and such will be found the general rule, when the circuit is closed upon the galvanometer without introducing the resistance of the body. Again, these instruments are constructed so differently, that the simple statement that "the needle was deflected ten or twenty degrees" signifies nothing, unless we know the properties of the particular galvanometer employed. But an instrument with which one has become familiar gives valuable information, of a practical sort, at all times. The actual presence of a current may always be ascertained by touching the tips of the conducting wires to

the sides of the tongue, if but three or four small cells are in circuit; if more, the application may be made to some less sensitive part, as the hand.

A very desirable piece of apparatus consists in an arrangement for instantaneous reversal of the current. Such an arrangement ("commutator") is not expensive. It ought to be tested before it is accepted of the maker.

The wire-rheostat is an instrument which enables us to graduate the strength of a current with great nicety. It is of decided advantage in treating diseases of the ear, but its cost is an obstacle to its general introduction. For practical purposes, a *water-rheostat* may be made to serve quite well, and costs only four or five dollars; it consists of one tube for fine graduation, and another for coarse, each of which is filled with a saturated solution of sulphate of zinc, in which a rod of zinc, connected with the battery, slides up and down; when this rod touches the bottom of the tube, it comes in contact with another piece of metal which completes the circuit, but in proportion as the tip of the rod is removed from this contact, the length of the column of water traversed by the current (and, therefore, the resistance) is increased. The zinc rods are amalgamated with mercury.[1]

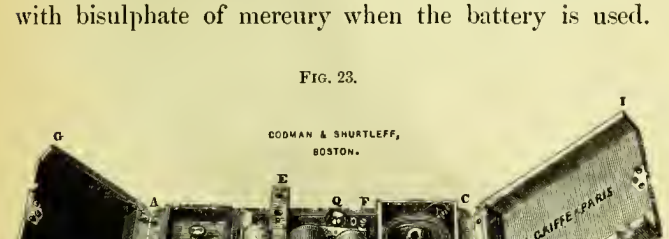
In the selection of a faradic coil the physician may be governed by his own sensations, if they are not revolted by the bare idea. The instrument must be capable of yielding a minimum current, which is scarcely perceptible to the tactile sense of the hand, but which can be raised to an intensity at least double that which a strong-nerved man is able to bear. Smoothness of current is

[1] Described in Deutsches Archiv f. klin. Med., vol. vii, Heft 6.

desirable; this depends very much on the mechanism of the hammer. An arrangement for increasing or diminishing the rapidity of vibration of the hammer is desirable, but not absolutely necessary.

The best pocket-battery is probably that of Gaiffe (Fig. 23), which gives a current strong enough for most purposes, and is easily managed. The figure shows two little zinc-carbon elements, which require to be charged with bisulphate of mercury when the battery is used.

FIG. 23.



Gaiffe's Pocket-battery.

The chloride of silver element, supplied with some of these batteries, is very liable to get out of order; the elements here given are to be depended on. Hall and others have constructed good portable batteries of somewhat greater size.

In applying electricity to the body, variously-shaped and constructed conductors, called *electrodes* or *rheophores*, are used. Such conductors, armed with a naked metal knob, are used for direct application to mucous surfaces; a bit of cotton batting may be wound tightly around the knob, if we choose. When applied to the skin a naked conductor is painful, especially if it has the shape of a point, or of a bundle of points (wire-

brush). To avoid pain, we employ a cap of thick cloth, or a covering of fine sponge, which when in use are thoroughly wetted with (salt) water. These coverings

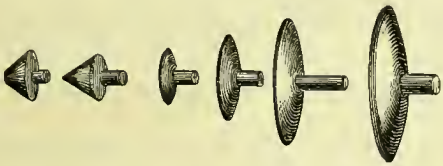
Fig. 24.

Small Faradic Apparatus by Hall.

diminish the force of the current, but serve to keep the skin moist, and in a considerable degree, to lessen the chemical irritation of the skin. A coat of rust may form upon the metal beneath the sponge, which destroys the conductive power of the implement. The metal of which the tips are made is commonly copper or bronze, and the salts of copper may give annoyance by staining the patient's clothes. To avoid this, we may plate with

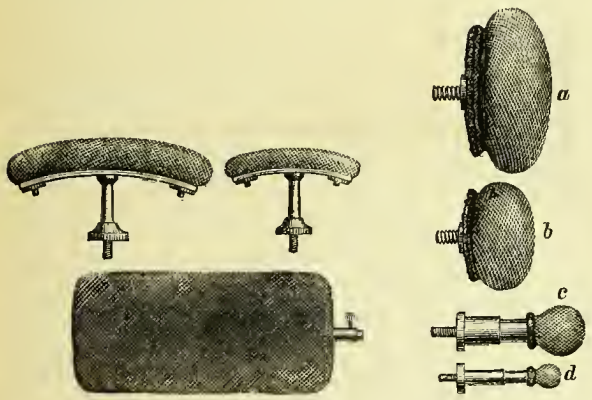
nickel, or with a film of platinum.[1] Carbon tips are perhaps more convenient than any others. They are

FIG. 25.



perfectly good conductors, and being made of porous coke they hold water like a sponge.

FIG. 26.



Sponge Electrodes, covered with Gauze.

The following are recommended as the most useful electrodes:

[1] Take of test-solution (10 p. c.) of bichloride of platinum 3 drops, water 1 ounce, or in this proportion; immerse the metal surface (well polished) for not more than five minutes. (Dr J. J. Putnam.)

1. Carbon-tipped, or sponge-capped, or cloth-covered; 2 or 3 inches in diameter;

2. Do., 1 inch;

3. Do., small knob;

4. Do., of elongated narrow form; say 3 inches by $\frac{1}{3}$ of an inch.

5. Metal plate, a foot square, to place the feet on or sit on.

6. Wire-brush.

7. Laryngeal electrode.

8. Urethral, vesical, uterine, and rectal electrodes. These are hollow bougies, bearing a metal knob at one

Fig. 27.

Wire-brush.

Fig. 28.

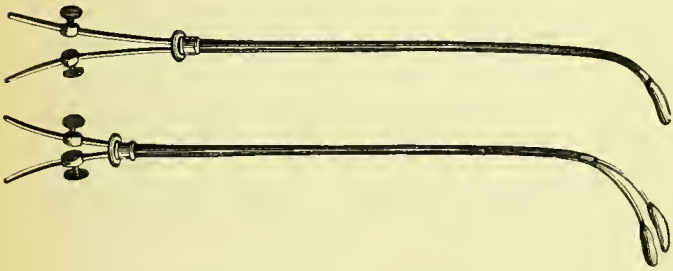
Laryngeal Electrode.

end, which is screwed to a rod running through the bougie. They may be constructed by the physician himself, if he has a mechanical turn; and if he chooses, he may add to his list one for the pharynx and Eustachian tube. That for the external auditory meatus consists of a rubber otoscope, in which a metal pin is so fixed as not to touch the living tissue; the instrument may be dispensed with.

A great variety of conductors might be enumerated, but to no purpose. One special modification, however, is quite important; the "unpolarizable" electrode of Du Bois-Reymond, as improved by Hitzig. This is con-

structed with the objeet of remedying the pain and the injury to the skin, which prevent the use of galvanie currents from a powerful battery for many minutes at onee. It eonsists of a tube of zine, amalgamated, and full of a concentrated solution of pure sulphate of zinc;

Fig. 29.



Duchenne's Double Vesical Electrode.

one end of the tube is closed, and in the other end is fixed a plug of potter's clay, saturated with a similar solution; over this plug comes a cap of paper-mass or elay, slightly moistened with salt water (two or three per cent. solution), whieh is applied to the skin of the body. The whole, except this eap, is inelosed in a hard rubber tube, for convenience. Hitzig was enabled by this instrument to pass a eurrent from forty cells (Daniell) for fifteen minutes, without occasioning diseomfort to the patient.

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